Consultative Committee for Space Data Systems

DRAFT RECOMMENDATION FOR SPACE DATA SYSTEM STANDARDS

PROXIMITY-1 SPACE LINK PROTOCOL

CCSDS 211.0-R-3

RED BOOK

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This Recommendation is published and maintained by:

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PREFACE

This document is a draft CCSDS Recommendation. Its Red Book status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process. Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 211.0-R-1	Proximity-1 Space Link Protocol, Red Book, Issue 1	May 1999	Original Issue (superseded)
CCSDS 211.0-R-2	Proximity-1 Space Link Protocol, Red Book, Issue 2	January 2000	Superseded
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1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide a draft Recommendation for Space Data System Standards in the area of Proximity space links. Proximity space links are defined to be short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. These links are characterized by short time delays, moderate (not weak) signals, and short, independent sessions.

1.2 SCOPE

This draft Recommendation defines the Data Link layer (with coding and synchronization, framing, media access, data services, and input-output sublayers). The specifications for error detection coding, synchronization, framing, addressing, and link control are defined, as well as the procedures for establishing and terminating a session between a caller and responder.

This draft Recommendation does not specify a) individual implementations or products, b) implementation of service interfaces within real systems, c) the methods or technologies required to perform the procedures, or d) the management activities required to configure and control the protocol.

1.3 APPLICABILITY

This draft Recommendation applies to the creation of Agency standards and to future data communications over space links between CCSDS Agencies in cross-support situations. It applies also to internal Agency links where no cross-support is required. It includes specification of the services and protocols for inter-Agency cross support. It is neither a specification of, nor a design for, systems that may be implemented for existing or future missions.

The Recommendation specified in this document is to be invoked through the normal standards programs of each CCSDS Agency and is applicable to those missions for which cross support based on capabilities described in this Recommendation is anticipated. Where mandatory capabilities are clearly indicated in sections of the Recommendation, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross support agreements between the Agencies involved.

1.4 RATIONALE

The CCSDS believes it is important to document the rationale underlying the recommendations chosen, so that future evaluations of proposed changes or improvements will not lose sight of previous decisions. Concept and rationale behind the decisions that formed the basis for Proximity-1 will be documented in the CCSDS Proximity-1 Space Link Green Book, which is still under development.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

1.5.1.1 Definitions from the Open Systems Interconnection (OSI) Basic Reference Model

This draft Recommendation makes use of a number of terms defined in reference [1]. The use of those terms in this draft Recommendation shall be understood in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are as follows:

a) blocking;

b) connection;

c) Data Link layer;

d) entity;

e) flow control;

f) network layer;

g) peer entities;

h) physical layer;

i) protocol control information;

j) Protocol Data Unit (PDU);

k) real system;

l) segmenting;

m) service;

n) Service Access Point (SAP);

o) SAP address;

p) Service Data Unit (SDU).

1.5.1.2 Definitions from OSI Service Definition Conventions

This draft Recommendation makes use of a number of terms defined in reference [2]. The use of those terms in this draft Recommendation shall be understood in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are as follows:

a) confirmation;

b) indication;

c) primitive;

d) request;

e) response;

f) service provider;

g) service user.

1.5.1.3 Terms Defined in This Draft Recommendation

For the purposes of this draft Recommendation, the following definitions also apply. Many other terms that pertain to specific items are defined in the appropriate sections.

asynchronous channel: a data channel where the symbol data are modulated onto the channel only for the period of the message. The message must be preceded by an acquisition sequence to achieve symbol synchronization, e.g., hailing channel. Bit synchronization must be reacquired on every message.

asynchronous data link: a channel consisting of a sequence of variable-length Proximity Link Transmission Units (PLTUs) which are not necessarily concatenated . Examples are: 1) Asynchronous Data Link over an Asynchronous Channel: Hailing is an example. An important issue is resynchronization between successive hails. Idle is provided for the reacquisition process. 2) Asynchronous Data Link over a Synchronous Channel: Once the link is established, one transitions to a synchronous channel and maintains the link in this configuration until the session is interrupted or ends. If the physical layer does not receive data from the data link layer, it provides idle to remain synchronous. Example is data service.

caller and responder: A **caller transceiver** is the initiator of the link establishment process and nominally manages the negotiation (if required) of the session. A **responder transceiver** is typically delegated to by the caller. The caller initiates communication between itself and a responder on a pre-arranged communications channel with - pre-defined controlling parameters. The caller and responder may negotiate (at some level between fully controlled and completely adaptive) as necessary the controlling parameters for the session.

COP-P: Command Operations Procedure-Proximity (COP-P). The COP-P includes both the FARM-P and FOP-P of the caller and responder unit.

FARM-P: Frame Acceptance and Reporting Mechanism for Sequence Controlled service carried out within the receiver in the Proximity-1 link.

FOP-P: Frame Operation Procedure for ordering the output frames for Sequence Controlled service carried out in the transmitter in the Proximity-1 link.

forward link: that portion of a Proximity space link in which the caller transmits and the responder receives (typically a command link).

hailing: the activity used to establish a Proximity link by a caller to a responder in either full or half duplex. It does not apply to simplex operations.

hailing channel: the forward and return frequency pairs that a caller and responder use to establish communications in which the configuration for a working session is established.

mission phase: a mission period during which specified communications characteristics are fixed. The transition between two consecutive mission phases may cause an interruption of the communications services.

P-frame: a Version 3 transfer frame which only contains self identified and self delimited supervisory protocol data units; cf. U-frame.

physical channel: The RF channel upon which the stream of bits is transferred over a space link in a single direction.

PLCW: Proximity Link Control Word. The PLCW is the protocol data unit for reporting Sequence Controlled service status via the return link from the responder back to the sender.

PLTU: The Proximity Link Transmission Unit is the data unit composed of the Attached Synchronization Marker, the Version-3 Transfer Frame, and the attached Cyclic Redundancy Check (CRC)-32.

Protocol object: directives, PLCWs, or status reports contained within an SPDU.

Proximity link: short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. These links are characterized by short time delays, moderate (not weak) signals, and short, independent sessions.

return link: the direction of a Proximity space link in which the responder transmits and the caller receives (typically a telemetry link).

session: a continuous dialog between two communicating Proximity link transceivers. It consists of three distinct operational phases: session establishment, data services, and session termination.

space link: a communications link between transmitting and receiving entities, at least one of which is in space.

SPDU: Supervisory Protocol Data Unit. Used by the local transceiver to either control or report status to the remote partnered transceiver. Consists of one or more directives, reports, or PLCWs.

synchronous channel: a continuous stream of bits at a fixed data rate. If the data link fails to provide frames (data or fill), it is the responsibility of the physical layer to provide the continuous bit stream.

synchronous data link: a continuous sequence of concatenated fixed-length **PLTUs** occurring in a fixed time interval (at a fixed data rate) without interruption of the modulation or insertion of any bits between PLTUs. A Synchronous Data Link over a Synchronous Channel is one example. Here the data link layer continuously provides bits to the physical layer. The example is block encoded data supplied during data services. It is important to note that the protocol by definition does not allow a synchronous data link with variable-length PLTUs.

U-frame: a Version 3 transfer frame which contains user data information; cf. P-frame.

Version-3 Transfer Frame: a Proximity-1 transfer frame.

working channel: a forward and return frequency pair used for transferring User data/information frames (U-frames) and Protocol/supervisory frames (P-frames) during the data service and session termination phases.

1.5.2 NOMENCLATURE

The following conventions apply throughout this draft Recommendation:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;
b) the word ‘should’ implies an optional, but desirable, specification;
c) the word ‘may’ implies an optional specification;
d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.5.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an *N*-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be ‘Bit 0’; the following bit is defined to be ‘Bit 1’ and so on up to ‘Bit *N*-1’.

When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., 'Bit 0', as shown in figure 1-1.

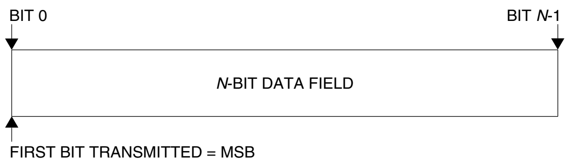


Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit 'words' that conform to the above convention. Throughout this draft Recommendation, such an 8-bit word is called an 'octet'.

The numbering for octets within a data structure begins with zero. Octet zero is the first octet to be transmitted.

By CCSDS convention, all 'spare' bits shall be permanently set to value 'zero'.

Throughout this draft Recommendation, directive, parameter, and signal names are presented with all upper-case characters; data-field and MIB-parameter names are presented with initial capitalization; parameter-value and state names are presented with predominantly lower-case characters, and are italicized.

1.6 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this draft Recommendation. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this draft Recommendation are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommendations.

[1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1. 2nd ed. Geneva: ISO, 1994.

[2] *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the definition of OSI services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.

[3] *Telecommand Part 2.1—Command Operation Procedures*. Recommendation for Space Data System Standards, CCSDS 202.1-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, June 2001.

[4] *Telecommand Part 2—Data Routing Service*. Recommendation for Space Data Systems Standards, CCSDS 202.0-B-3. Blue Book. Issue 3. Washington, D.C.: CCSDS, June 2001.

[5] *Packet Telemetry*. Recommendation for Space Data System Standards, CCSDS 102.0-B-5. Blue Book. Issue 5. Washington, D.C.: CCSDS, November 2000.

[6] *Telemetry Channel Coding*. Recommendation for Space Data System Standards, CCSDS 101.0-B-5. Blue Book. Issue 5. Washington, D.C.: CCSDS, June 2001.

[7] *CCSDS Global Spacecraft Identification Field Code Assignment Control Procedures*. Recommendation for Space Data System Standards, CCSDS 320.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, October 1998.

[8] *CCSDS Time Code Formats.* Recommendation for Space Data System Standards, CCSDS 301.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, April 1990.

2 OVERVIEW

2.1 CONCEPT OF PROXIMITY-1

2.1.1 LAYERED MODEL

Proximity-1 is a data link protocol specification and as such it does not define the physical link. It does not include any details associated with physical characteristics, such as frequencies, modulations, channel coding, data rates, and radiometric data requirements. It does, however, provide a concise functional description of the physical layer to set the context for this draft Recommendation.

Proximity-1 is a bi-directional Data Link layer protocol to be used by space missions. This protocol has been designed to meet the requirements of space missions for efficient transfer of space data over various types and characteristics of Proximity space links. The Data Link layer is responsible for providing data to be transmitted to the physical layer. The operation of the transmitter is state-driven. On the receive side, this layer accepts the serial data output from the receiver and processes the protocol data units received. It accepts directives both from the local spacecraft controller and across the Proximity link to control its operations. Once the receiver is turned on, its operation is modeless. It accepts and processes all valid local and remote directives and received service data units.

The Data Link layer has five component sublayers:

a) Coding and Synchronization. The Coding and Synchronization (C&S) sublayer (see 4.1) includes PLTU delimiting and verification procedures. In addition this sublayer:

   1) On the send side:

      a) includes pre-pending Version-3 frames with the required Attached Synchronization Marker (ASM);

      b) includes addition of CRC-32 to PLTUs.

   2) On both the send and receive sides: Captures the value of the clock used for time correlation process.

b) Frame. The Frame sublayer (see 4.2) includes frame validation procedures, such as transfer frame header checks, and supervisory data processing for supervisory frames. In addition this sublayer:

   1) On the send side:

      a) includes the Input/Output (I/O) sublayer-provided user data (SDUs) into Version-3 frames;

      b) prioritizes and multiplexes the frames for output via the C&S sublayer to the Physical layer for transmission across the link.

   2) On the receive side:

a) accepts delimited and verified frames from the C&S sublayer;

b) delivers supervisory protocol data units (reports, directives) to the MAC sublayer;

c) passes the user data to the Data Services Sublayer;

d) performs a subset of validation checks to ensure that the received data should be further processed.

c) Medium Access Control. The Medium Access Control (MAC) sublayer (see 4.3) defines how a session is established, maintained (and how characteristics are modified, e.g., data rate changes), and terminated for point-to-point communications between network assets; this sublayer builds upon the physical and Data Link layer functionality. The MAC controls the operational state of the Data Link and Physical layers. It accepts and processes Supervisory Protocol Data Units (SPDUs) and provides the various control signals that dictate the operational state. In addition this sublayer:

1) decodes the directives from the local vehicle's controller (e.g., spacecraft control computer);

2) decodes the directives received via the remote transceiver (extracting and processing SPDUs from the Frame Data Field);

3) stores and distributes the Managment Information Base (MIB) parameters (implementation-specific) and status variables;

4) maintains and distributes the State control parameters (MODE, TRANSMIT, DUPLEX, see 4.1.2.1);

5) provides status information to the local vehicle controller.

d) Data Services. The Data Services sublayer (see 4.4) defines the Frame Acceptance and Reporting Mechanism (FARM) (receive side) and the Frame Operations Procedures (FOP) (send side) associated with the Expedited and Sequence Controlled data services including how the FOP-P and FARM-P (COP-P) operate in the Sequence Controlled service.

e) Input/Output. The Input/Output (I/O) interface sublayer (see 4.5) provides the interface between the transceiver and the on-board data system and their applications. In addition, this sublayer:

1) On the receive side:

a) accepts received U-frames;

b) extracts the SDUs from U-Frames;

c) provides required packet aggregation services;

d) routes SDUs to data service users via the specified Port ID.

2) On the send side: Accepts local user-provided SDUs and associated routing and control information(SCID, PCID, Source/Destination ID, QOS, Port ID):

a) aggregates these SDUs as required to form U-frame data fields;

b) provides required packet segmentation services;

c) delivers these U-frame data fields to the Data Services sublayer;

d) delivers acknowledgements to spacecraft vehicle controller for SDUs delivered via Sequence Controlled Service.

The interactions of the Proximity-1 layers and associated data and control flows are shown in figure 2-1.

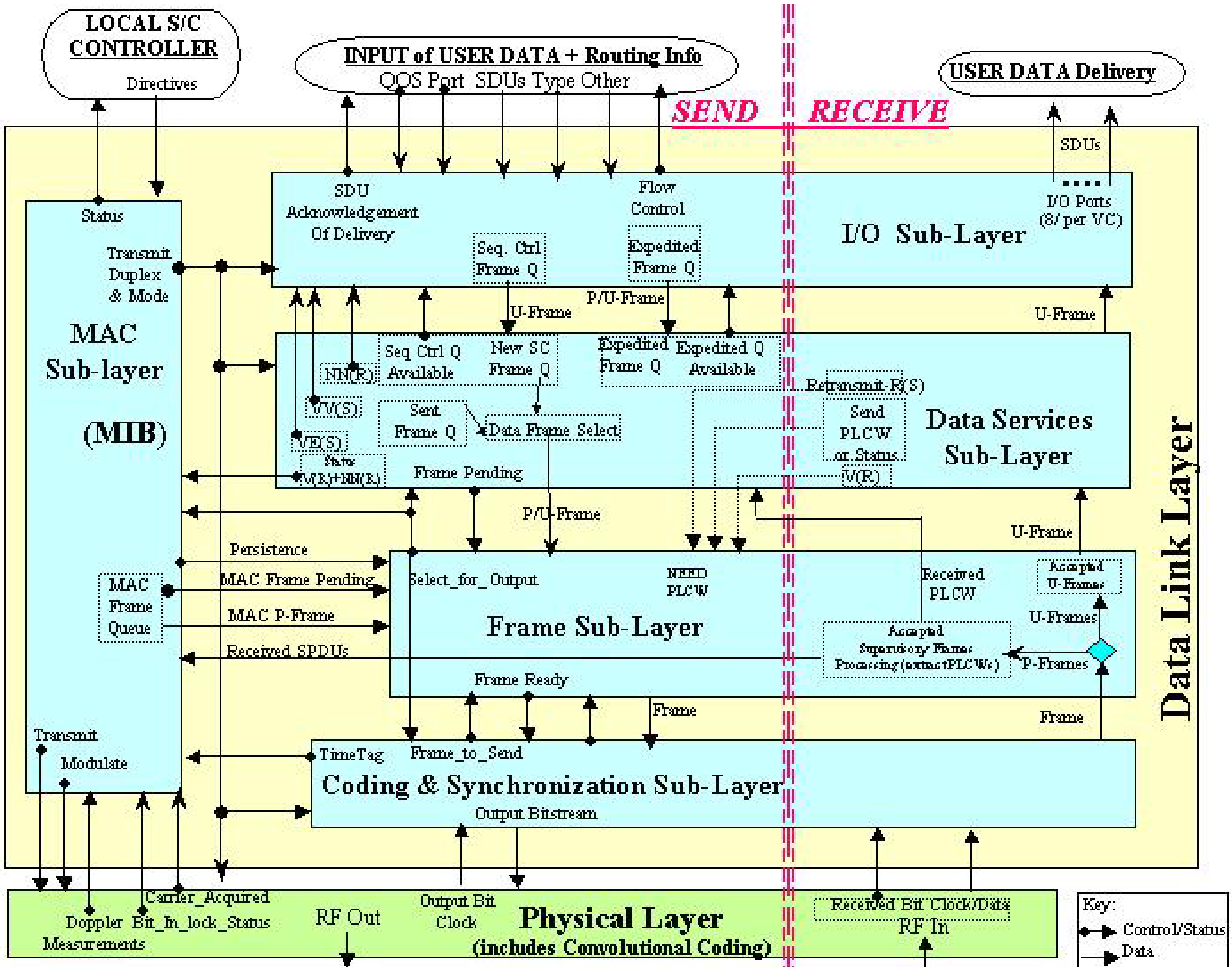


Figure 2-1: Proximity-1 Layered Protocol Model

2.1.2 PROTOCOL-UNIQUE FEATURES

The Proximity-1 protocol controls and manages data interchange across the communications link. This Data Link layer protocol provides the capability to send user data, control reports, and control directives between the transceiver units. The directives are used for selection of communications frequencies, data rates, modulation, coding, and link directionality (full duplex, half duplex, and simplex). The Data Link layer provides for the transfer of both packets and user-defined data units. All of these units can be transferred using either an Expedited or a Sequence Controlled (reliable) Service supportive of applications involving remote space vehicles.

The terms 'Transfer Frame' and 'frame' in this text refer to the Version-3 Transfer Frame. Each Transfer Frame contains a header, which provides protocol control information for processing the Transfer Frame data field. This data field contains either:

a) Service Data Units (SDUs) i.e., user data for delivery to applications within the receiving node;

b) Supervisory Protocol Data Units (SPDUs):

    1) protocol directives:

        a) for configuring and controlling the protocol processor at the receiving node;

        b) for the establishment, maintenance, and termination of a communications session.

    2) protocol reports:

        a) for reporting the configuration and status of the transmitting node;

        b) for reporting the status of a Sequence Controlled data transfer operating in the opposite direction, i.e., PLCW.

The list of protocol directives and reports is extended for use in controlling and reporting status for the physical layer process when the Data Link layer and Physical layers are collocated.

2.1.3 PLTU TYPE

The PLTU is flexibly sized to fit its variable-length data content (e.g., variable-length frame containing variable-length packets). This PLTU is intended for use on links characterized by short time delays, moderate (not weak) signals, and short, independent sessions. These link characteristics determine the type of ASM (24-bit), its associated bit error tolerance for synchronization (MIB parameter), and coding (32-bit Cyclic Redundancy Check) employed for the PLTUs. Symbol and bit synchronization is maintained in the data channel by the insertion of an idle sequence between PLTUs, and these variable-length PLTUs are only inserted into the data link when a physical connection has been achieved. The data field of a variable-length frame can contain an integer number of unsegmented packets, a single packet segment, or a collection of user-provided octets.

2.1.4 ADDRESSING

A triad of addressing capabilities is incorporated for specific functionality within the link. The Spacecraft Identifier (SCID) identifies the source or destination of Transfer Frames transported in the link connection based upon the Source-or-Destination Identifier. The Physical Channel Identifier (PCID) provides two independently multiplexed channels, each capable of supporting both the Sequence Controlled and Expedited services. The Port ID provides the means to route user data internally (at the transceiver's output interface) to specific logical ports, such as applications or transport processes, or to physical ports, such as on-board buses or physical connections (including hardware command decoders).

2.1.5 PROTOCOL DESCRIPTION

The Proximity-1 protocol is described in terms of:

a) the services provided to the users (transfer of SDUs);

b) the Protocol Data Units (PDUs);

c) the protocol directives and reports (SPDUs described in 3.2.8);

d) the procedures performed by the protocol as described in the state tables.

The service definitions, which will be supplied in a subsequent version of this document, are given in the form of primitives, which present an abstract model of the logical exchange of data and control information between the protocol and the service user. The definitions of primitives are independent of specific implementation approaches.

The procedure specifications, which will be supplied in a subsequent version of this document, define the procedures performed by protocol entities for the transfer of information between peer entities. The definitions of procedures are independent of specific implementation methods or technologies.

This protocol specification also defines the requirements for the underlying services provided by lower layers.

2.2 OVERVIEW OF SERVICES

2.2.1 COMMON FEATURES OF SERVICES

Proximity-1 provides users with data transfer services known as Space Data Link Proximity-1 services. The point at which a service is provided by a protocol entity to a user is called a

Service Access Point (SAP). For each Physical Channel (PC), there are two receiving SAPs (one for Sequence Controlled Service, and the other for Expedited Service) through which input data (SDUs) are received (presumably from the spacecraft vehicle controller). There are also eight output SAPs (port addresses) through which received telemetered data are distributed to the on-board data systems and their applications.

2.2.2 SERVICE TYPES

2.2.2.1 General

The Proximity-1 protocol provides data and timing services. Data services are of two types: The first accepts and delivers packets, while the second accepts and delivers user-defined data. The timing service provides time stamping upon ingress/egress of selected PLTUs. See 5.1 for details on the Proximity-1 Timing Service.

2.2.2.2 CCSDS Packet Delivery Service

The packet delivery service provides for the transfer of packets (CCSDS source packets, Space Communications Protocol Standards-Network Protocol [SCPS-NP] packets, IPv4 packets, encapsulation packets; see reference [5]) across the Proximity space link. The packets are multiplexed into transfer frames (when they are smaller than the maximum frame data field size allowed in the link), or they are segmented before being inserted into transfer trames and then reassembled into packets for delivery (when they are greater than the maximum frame data field size allowed in the asynchronous link). In this service the delivery process makes use of the Port ID to identify the specific physical or logical port through which the packet is to be routed.

2.2.2.3 User Defined Data Delivery Service

The user defined data delivery service provides for the transfer of a single user's collection of octets (format unknown to the protocol) via the Port ID specified in the Transfer Frame Header. The service does not utilize any information from the Frame Data field. The user data will be placed in one or more frames as required based upon the size of the received data. In this service the delivery process makes use of the Port ID to identify the specific physical port through which the octets are to be routed.

2.2.2.4 Timing Service

Timing services are required for Proximity operations in order to provide time (spacecraft clock) correlation data among communicating units and time-derived ranging measurements. See 5.1.

2.2.3 SERVICE QUALITIES

2.2.3.1 General

The Proximity-1 data services protocol provides two grades of service (Sequence Controlled and Expedited) that determine how reliably SDUs supplied by the sending user are delivered to the receiving user. This Protocol is called COP-P and consists of a Frame Operational Procedure Proximity (FOP-P) used on the sending side of the service, and a Frame Acceptance and Reporting Mechanism Proximity (FARM-P) used on the receiving side of the service.

Each of these two service grades is accessed through its own SAP. For each SDU, the user must additionally specify the output port through which the data is to be delivered by the receiving transceiver and the type of data units provided. Packetized data units that are larger then the maximum frame size in asynchronous frames can be transferred only by using the segmentation process, utilizing either the Sequence Controlled service or the Expedited service.

2.2.3.2 Sequence Controlled Service

The Sequence Controlled service ensures that data is reliably transferred across the space link and delivered in order, without gaps, errors, or duplications within a communication session. This service is based on a 'go-back-n' type of Automatic Repeat Queuing (ARQ) procedure that utilizes sequence-control mechanisms of both sending and receiving ends and a standard report, i.e., PLCW returned from the receiving end to the sending end.

Sequence Controlled SDUs supplied by a sending user at the Sequence Controlled SAP are inserted into transfer frames as required and transmitted on a Physical Channel (PC) initially in the order in which they are presented at the SAP. SDUs are passed to the receiving user via the identified port. The retransmission mechanism ensures with a high probability of success that:

a) no SDU is lost;

b) no SDU is duplicated;

c) no SDU is delivered out of sequence.

2.2.3.3 Expedited Service

The Expedited service is nominally used with upper-layer protocols that provide their own retransmission features, or in exceptional operational circumstances such as during spacecraft recovery operations.

Expedited SDUs supplied by the sending user are transmitted without ARQ. At the sending end, Expedited SDUs are transmitted on specified PCs independently of the Sequence Controlled SDUs waiting to be transmitted on the same PC. At the receiving end, the SDUs are passed to the receiving user via the identified port. Note that Expedited SDUs may be sent once or multiple times, but they are not sent again as a result of a request for retransmission. If such a request occurs it is performed outside the purview of the protocol.

There is no guarantee that all Expedited SDUs will be delivered to the receiving user. Expedited service delivers only complete SDUs to the user.

NOTE – In Expedited service the capability is provided to deliver portions of user-defined data units that are greater than the maximum frame size allowed for the link.

3 PROTOCOL DATA UNITS

3.1 CONTEXT OF THE VERSION-3 TRANSFER FRAME

See figure 3-1 for the Proximity-1 protocol data unit context diagram.

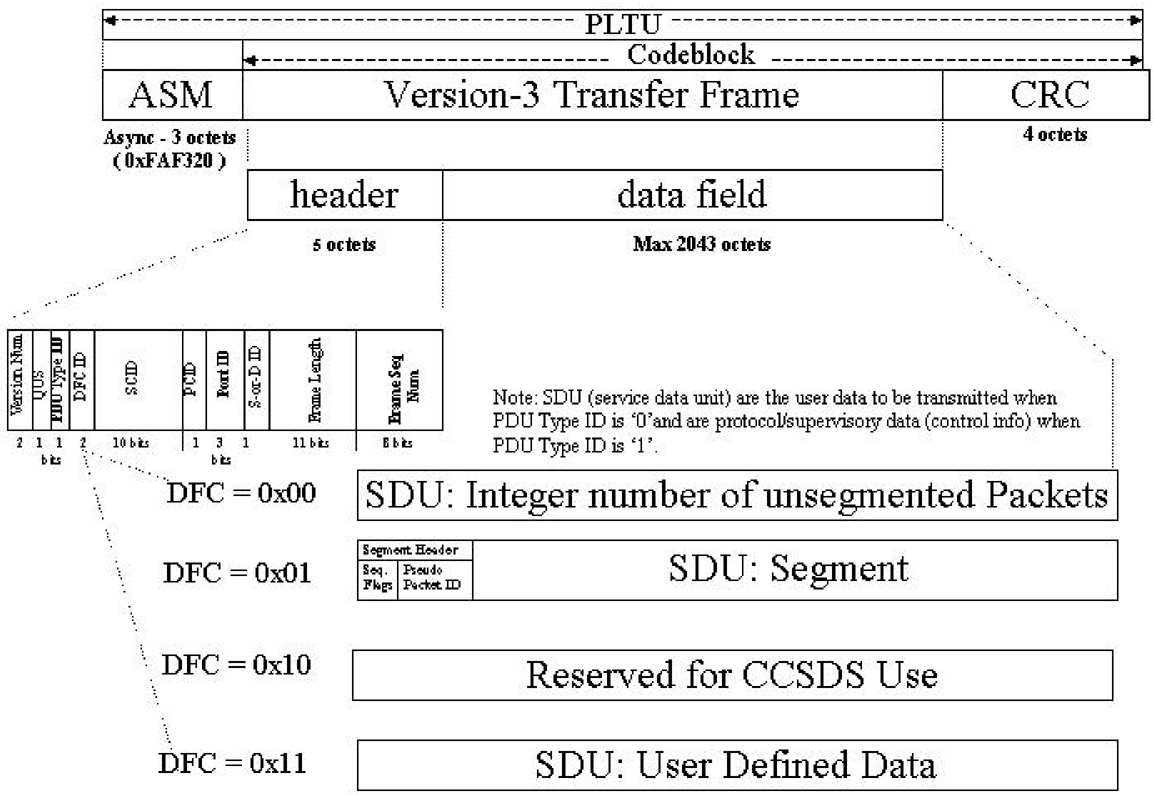


Figure 3-1: Proximity-1 Protocol Data Unit Context Diagram

3.2 VERSION-3 TRANSFER FRAME

3.2.1 VERSION-3 TRANSFER FRAME STRUCTURE

A Version-3 Transfer Frame shall encompass the following fields, positioned contiguously, in the following sequence:

a) Transfer Frame Header (five octets, mandatory);

b) Transfer Frame Data Field (up to 2043 octets).

NOTES

1 The Version-3 Transfer Frame is the PDU transmitted from the sending end to the receiving end by Proximity-1.

2 The maximum Transfer Frame length allowed by a particular spacecraft or ground implementation on a particular PC may be less than the maximum specified here.

3 The composition of the Version-3 Transfer Frame is shown in figure 3-2.

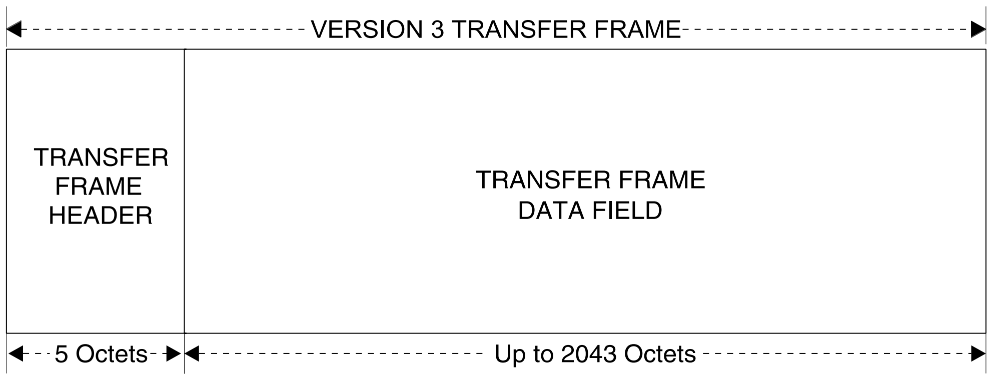


Figure 3-2: Version-3 Transfer Frame

3.2.2 TRANSFER FRAME HEADER

3.2.2.1 Summary of Header Fields

The Transfer Frame Header is mandatory and shall consist of ten mandatory fields, positioned contiguously, in the following sequence:

a) Transfer Frame Version Number (2 bits);

b) Quality of Service (QOS) Indicator (1 bit);

c) Protocol Data Unit (PDU) Type ID (1 bit);

d) Data Field Construction Identifier (DFC ID) (2 bits);

e) Spacecraft Identifier (SCID) (10 bits);

f) Physical Channel Identifier (PCID) (1 bit);

g) Port ID (3 bits);

h) Source-or-Destination Identifier (reference [7]) (1 bit);

i) Frame Length (11 bits);

j) Frame Sequence Number (Interpretation is QOS dependent) (8 bits).

NOTE – The format of the Transfer Frame Header is shown in figure 3-3.

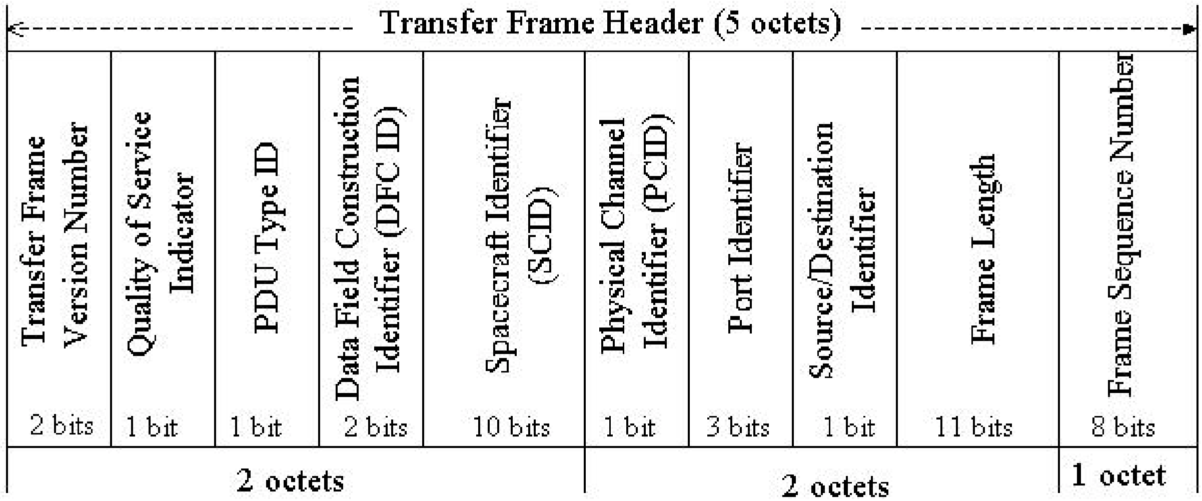


Figure 3-3: Transfer Frame Header

3.2.2.2 Transfer Frame Version Number

3.2.2.2.1 Bits 0–1 of the Transfer Frame Header shall contain the Transfer Frame Version Number.

3.2.2.2.2 The Transfer Frame Version Number field shall contain the binary value ‘10’.

NOTE – This draft Recommendation defines the Version-3 Transfer Frame. For other Transfer Frames defined by CCSDS for use with other protocols, see references [4] and [5].

3.2.2.3 Quality of Service Indicator

3.2.2.3.1 Bit 2 of the Transfer Frame Header shall contain the QOS Indicator.

3.2.2.3.2 The single-bit QOS Indicator shall control the application of Frame Acceptance Checks by the receiving end.

a) Setting this Indicator to ‘0’ specifies that this Transfer Frame is a Sequence Controlled Transfer Frame, and acceptance of this Transfer Frame by the receiving end shall be subject to the Frame Acceptance Checks, which provide the ‘reliable’ Sequence Controlled service.

b) Setting this indicator to ‘1’ specifies that this Transfer Frame is an Expedited Transfer Frame, and the Frame Acceptance Checks used for Sequence Controlled service by the receiving end shall be bypassed.

3.2.2.4 PDU Type ID

3.2.2.4.1 Bit 3 of the Transfer Frame Header shall contain the PDU Type ID.

3.2.2.4.2 The PDU Type ID shall be used to specify whether the Transfer Frame Data field is conveying protocol supervisory data or user data information.

a) Setting the PDU Type ID to ‘0’ indicates that the Transfer Frame Data field contains user data information.

b) Setting the PDU Type ID to ‘1’ indicates that the Transfer Frame Data field contains supervisory protocol data, i.e., control information, used for controlling operations of the Proximity-1 protocol processor. See 3.2.8 for an explanation of when this PDU type must be used.

3.2.2.5 Data Field Construction ID

3.2.2.5.1 Bits 4–5 of the Transfer Frame Header shall contain the Data Field Construction ID (DFC ID).

3.2.2.5.2 The DFC ID shall signal the data field construction rules used to build the Frame Data field.

3.2.2.5.3 The four frame data field construction rules are defined in table 3-1.

Table 3-1: Frame Data Field Construction Rules

DFC ID	PLTU Type	Frame Data Field Content	Subsection
‘00’	Asynchronous	Packets (integer number of unsegmented packets)	3.2.4
‘01’	Asynchronous	Segment Data (a complete or segmented packet)	3.2.5
‘10’	Reserved for future CCSDS definition.	Reserved for future CCSDS definition.	3.2.6
‘11’	Asynchronous	User-defined Data	3.2.7

3.2.2.6 Spacecraft Identifier (SCID)

3.2.2.6.1 Bits 6–15 of the Transfer Frame Header shall contain the SCID.

3.2.2.6.2 The 10-bit SCID shall provide the identification of the spacecraft that is either the source or the destination of the data contained in the Transfer Frame.

NOTE: See Source or Destination Identifier for the definition of the value of the SCID.

3.2.2.7 Physical Channel Identifier (PCID)

3.2.2.7.1 Bit 16 of the Transfer Frame Header shall contain the PCID.

3.2.2.7.2 The PCID shall be used to address one of two redundant transceivers (physical channels).

3.2.2.8 Port ID

3.2.2.8.1 Bits 17–19 of the Transfer Frame Header shall contain the Port ID.

3.2.2.8.2 The Port ID shall be used to address different physical or logical connection ports to which user data is to be routed.

NOTE – There are 8 Port IDs. Port IDs are independent of proximity channel assignment.

EXAMPLE – A Port ID could designate that the contents of the Frame Data field should be delivered via the addressed physical data port (e.g., a port to a spacecraft bus), or to a defined process within the connected command and data handling system.

3.2.2.9 Source/Destination Identifier

3.2.2.9.1 Bit 20 of the Transfer Frame Header shall contain the Source-or-Destination Identifier.

3.2.2.9.2 The Source-or-Destination Identifier shall identify the link node to which the value in the SCID field applies:

a) a setting of ‘0’ shall indicate that:

   1) the SCID refers to the SOURCE of the Transfer Frame,

   2) the test of the SCID shall only be included in the Frame sublayer when TEST_SOURCE is *true*;

b) a setting of ‘1’ shall indicate that:

   1) the SCID refers to the DESTINATION of the Transfer Frame,

   2) the test of the SCID shall be included in the frame sublayer.

3.2.2.9.3 When the Source/Destination ID set to ‘0’, i.e., Source, the value of the SCID shall be contained in the MIB parameter, Local_Spacecraft_ID.

NOTE – Assignment procedures for SCIDs in Proximity-1 Transfer Frames are controlled by reference [7].

3.2.2.9.4 When the Source/Destination ID is set to ‘1’, i.e., Destination, the value of the SCID shall be contained in the MIB parameter, Remote_Spacecraft_ID.

3.2.2.10 Frame Length

3.2.2.10.1 Bits 21–31 of the Transfer Frame Header shall contain the frame length.

3.2.2.10.2 This 11-bit field shall contain a length count C, which equals one fewer than the total number of octets in the Transfer Frame.

a) The count shall be measured from the first octet of the Transfer Frame Header to the last octet of the Transfer Frame Data field.

b) The length count C is expressed as: C = (total number of octets in the Transfer Frame) – 1

NOTE – The size of the Frame Length field limits the maximum length of a Transfer Frame to 2048 octets ($C = 2047$). The minimum length is 5 octets ($C = 4$).

3.2.2.11 Frame Sequence Number (Sequence_Controlled or Expedited)

3.2.2.11.1 Bits 32–39 of the Transfer Frame Header shall contain the Frame Sequence Number (FSN).

3.2.2.11.2 The FSN shall increment monotonically and independently for the set of frames within a PC that are associated with the Sequence Controlled Service (Quality of Service Indicator set to ‘0’). In this case, the FSN shall be called the Sequence_Controlled_FSN (SEQ_CTRL_FSN).

3.2.2.11.3 The FSN shall increment monotonically for the set of frames for a given PC that are associated with the Expedited Data Service (QOS Indicator set to ‘1’). In this case, the FSN shall be called the Expedited_FSN (EXP_FSN).

NOTES

1 The FSN (controlled within the Data Services Sublayer) for each service is initialized to ‘0’ by the Set Initialize (MODE) directive (see 6.3.7.)

2 The SEQ_CTRL_FSN enables the Sequence Controlled process to number sequentially and then check the sequentiality of incoming Sequence Controlled Transfer Frames.

3 The EXP_FSN is not used in the frame validation process but is required for correlations associated with timing services.

4 The FSN is PC-dependent for both the Sequence Controlled and Expedited services.

3.2.3 TRANSFER FRAME DATA FIELD

The Transfer Frame Data field shall:

a) follow, without gap, the Transfer Frame Header;

b) be of variable length;

c) contain from zero octets up to 2043 octets provided by the Frame Length field, minus five octets limited by the PLTU length;

d) contain either an integer number of octets of data corresponding to one or more SDUs, or an integer number of octets of protocol information.

NOTE – These octets may contain an SDU and other data fields based upon the DFC ID. See figure 3-4.

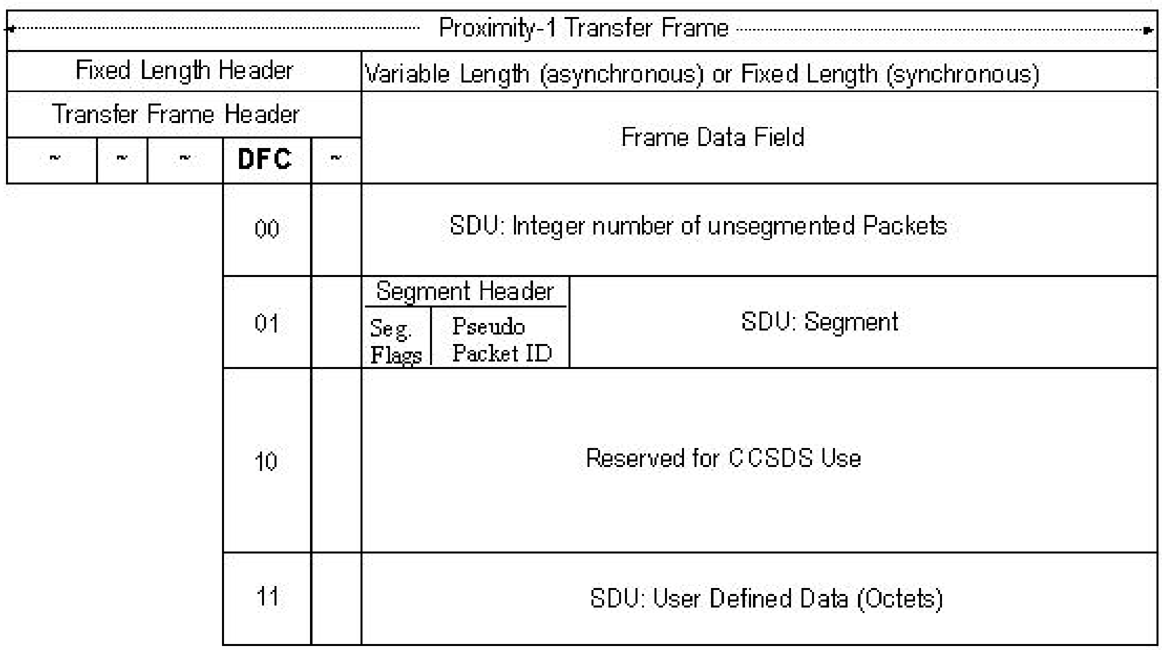


Figure 3-4: Proximity-1 Transfer Frame Data Field Structure

3.2.4 PACKETS

3.2.4.1 When the DFC ID field contains the binary value ‘00’ (pertaining to asynchronous PLTUs), the Frame Data field shall consist of an integer number of packets each designated to the same Port ID (see figure 3-4).

3.2.4.2 The first bit of the Frame Data field shall be the first bit of a packet header.

3.2.5 SEGMENT DATA UNITS

3.2.5.1 When the DFC ID field contains the binary value ‘01’ (pertaining to asynchronous PLTUs), the Frame Data field contains a Segment Data Unit consisting of an eight-bit segment header followed by a segment of a packet (see figure 3-4).

3.2.5.2 The contents of the segment header and segment data field shall be as follows:

a) bits 0 and 1 of the segment header compose the sequence flag, which shall identify the position of the segment relative to the packet of which the segment is a part as specified in table 3-2;

b) the remaining six bits compose an identifier field, the pseudo packet identifier, which shall adaptively be used to associate all the segments of a packet data unit;

c) segments must be placed into the data link in the proper order:

   1) segments of the same packet must be sent in frames of the same PCID and Port ID;

   2) segments from another packet may be interspersed but only in frames containing a different PCID or Port ID.

Table 3-2: Segment Header Sequence Flags

Sequence Flags	Interpretation
‘01’	first segment
‘00’	continuing segment
‘10’	last segment
‘11’	no segmentation (i.e., contains the entire packet)

3.2.5.3 Prior to delivery to the user, the Data Link layer shall re-assemble all the segments using the same Routing ID, i.e., using the same PCID, Port ID, and pseudo packet ID, into a packet.

3.2.5.4 Only complete packets shall be sent on to the user.

3.2.5.5 The accumulated packet shall be discarded and this event shall be logged into the session accountability report whenever any of the following errors occur:

a) the packet length field does not agree with the number of bytes received and aggregated from the segments;

b) the first segment received for a Routing ID is not the start segment of the data unit;

c) the last segment for a Routing ID is not received before the starting segment of a new packet is received.

3.2.6 CCSDS RESERVED FIELD

When the DFC ID field contains the binary value '10', the Frame Data field shall be reserved for CCSDS use. (see figure 3-4).

3.2.7 USER-DEFINED DATA

When the DFC ID field contains the binary value '11', the Frame Data field shall consist of User Defined Data (see figure 3-4).

3.2.8 SUPERVISORY PDU (SPDU)

3.2.8.1 The protocol data units discussed in this subsection are used by the local transceiver to either control or report status to the remote transceiver acting as the communication partner over the proximity space link, or for local control within the transceiver.

3.2.8.2 SPDUs are either fixed- or variable-length based upon the value of the SPDU format ID. Currently there is only one fixed-length SPDU defined, i.e., PLCW. Variable-length SPDUs provide the capability for concatenating and multiplexing protocol objects, i.e., directives, status reports, and PLCWs. Note that the positions of the individual fields within the fixed-length PLCW differ from those of the variable-length PLCW. Each SPDU Type is further described in tables 3-3 and 3-4.

3.2.8.3 SPDUs can be transmitted using only the expedited QOS (QOS = '1').

3.2.8.4 SPDUs are all self-identifying and self-delimiting. Only variable-length SPDUs further decompose into specific types of supervisory directives, reports or PLCWs. See annex A for the detailed specification of variable-length SPDUs.

3.2.8.5 Overview of SPDU Formats

3.2.8.5.1 Fixed-length SPDUs consist of a SPDU Format ID, SPDU Type Identifier, and a Supervisory Data Field. Variable-length SPDUs consist of a SPDU Format ID, SPDU Type Identifier, length of SPDU field, and a Supervisory Data Field.

3.2.8.5.2 For fixed-length SPDUs these fields are defined and are positioned contiguously, in the following sequence as:

a) SPDU Header (two bits) consist of:

   1) SPDU Format ID (one bit);

   2) SPDU Type Identifier (one bit).

b) Supervisory data field (14 bits): this field contains either the data field of a fixed-length PLCW or the data field of a CCSDS reserved SPDU.

3.2.8.5.3 For variable-length SPDUs, these fields are defined and are positioned contiguously, in the following sequence as:

a) SPDU Header (one octet) consists of:

   1) SPDU Format ID (one bit);

   2) SPDU Type Identifier (three bits);

   3) Data Field Length (four bits) (this represents the actual number of octets in the data field of the SPDU).

NOTE – This is not a 'length minus one' field.

b) Supervisory data field (variable length, i.e., 0 to 15 octets): this field shall consist of one or more supervisory directives, status reports, or PLCWs of the same SPDU type.

Table 3-3: Fixed-length Supervisory Protocol Data Unit

Fixed-length SPDU (16 bits)	**SPDU Header (2 bits)**		**SPDU Data Field (14 bits)**
	SPDU Format ID (Bit 0)	SPDU Type Identifier (Bit 1)	(contains 1 protocol objects i.e., directive or report or PLCW) (Bits 2 through 15)
Type 01	'1'	'0'	See 3.2.8.6.1
Type 02	'1'	'1'	Reserved for CCSDS Use

3.2.8.6 Fixed-length SPDU

3.2.8.6.1 General

A '1' in the SPDU Format ID field identifies a 16-bit fixed-length SPDU. This format provides for only two fixed SPDUs which are differentiated by the SPDU Type Identifier field. A 'zero' in bit 1 identifies the SPDU as a PLCW, while a SPDU identified by a 'one' is reserved for future CCSDS specification.

3.2.8.6.2 Type 01 SPDU: Proximity Link Control Word (PLCW)

3.2.8.6.2.1 Overview

The Proximity Link Control Word (PLCW) shall consist of seven fields, positioned contiguously, in the following sequence:

a) SPDU Format ID (one bit);

b) SPDU Type Identifier (one bit);

c) Retransmit Flag (one bit);

d) PCID (one bit);

e) Reserved Spare (one bit);

f) Expedited Frame Counter (three bits);

g) Report Value (eight bits).

NOTE – The structural components of the PLCW are shown in figure 3-5. This format only applies to the fixed-length PLCW, i.e., it does not apply to the PLCW defined in the variable-length SPDU section.

Bit 0 … Bit 15

SPDU Header		SPDU Data Field				
SPDU Format ID 1 bit	SPDU Type Identifier 1 bit	Retrans-mit Flag 1 bit	PCID 1 bit	Reserved Spare 1 bit	Expedited Frame Counter 3 bits	Report Value (Frame Sequence Number) 8 bits

Figure 3-5: Proximity Link Control Word Fields

NOTE – It is mandatory to transmit the PLCW using the Expedited QOS.

3.2.8.6.2.2 Report Value

3.2.8.6.2.2.1 Bits 8–15 of the PLCW shall contain the Report Value.

3.2.8.6.2.2.2 The Report Value field shall contain the next sequence controlled Frame Sequence Number (SEQ_FSN).

3.2.8.6.2.2.3 Separate Report Values shall be maintained for each PC independent of the I/O port.

3.2.8.6.2.3 Expedited Frame Counter

3.2.8.6.2.3.1 Bits 5–7 of the PLCW shall contain the Expedited Frame Counter.

3.2.8.6.2.3.2 The Expedited Frame Counter shall provide a modulo-8 counter indicating that Expedited frames have been received.

3.2.8.6.2.4 Reserved Spare

3.2.8.6.2.4.1 Bit 4 of the PLCW shall contain a Reserved Spare bit.

3.2.8.6.2.4.2 The Reserved Spare bit field shall be set to ‘0’.

3.2.8.6.2.5 Proximity Channel Identification

3.2.8.6.2.5.1 Bit 3 of the PLCW shall contain the PCID field.

3.2.8.6.2.5.2 The one-bit PCID field shall contain the PCID of the Physical Channel with which this report is associated.

NOTE – Each PCID in use has its own PLCW reporting activated.

3.2.8.6.2.6 PLCW RETRANSMIT FLAG

3.2.8.6.2.6.1 Bit 2 of the PLCW shall contain the PLCW Retransmit Flag.

3.2.8.6.2.6.2 A setting of ‘0’ in the PLCW Retransmit Flag shall indicate that there are no outstanding frame rejections in the sequence received so far, and thus retransmissions are not required.

3.2.8.6.2.6.3 A setting of ‘1’ in the PLCW Retransmit Flag shall indicate that a received frame failed a frame acceptance check and, therefore, that a retransmission of that frame is required.

3.2.8.6.2.7 SPDU TYPE IDENTIFIER

3.2.8.6.2.7.1 Bit 1 of the PLCW shall contain the SPDU Type Identifier.

3.2.8.6.2.7.2 The one-bit SPDU Type Identifier field shall identify SPDU type as a PLCW and shall contain the binary value ‘0’.

3.2.8.6.2.8 SPDU FORMAT ID

3.2.8.6.2.8.1 Bit 0 of the PLCW shall contain the SPDU Format ID.

3.2.8.6.2.8.2 The one-bit SPDU format ID field shall identify the SPDU as fixed-length and shall contain the binary value ‘1’.

Table 3-4: Variable-length Supervisory Protocol Data Unit

Variable-length SPDU	SPDU Header (1 octet, fixed)			SPDU Data Field (0-15 bytes)
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(contains 1 or more protocol objects i.e., directives, reports, PLCWs)
Type 1	'0'	'000'	Length	Directives/Reports/PLCWs (see note)
Type 2	'0'	'001'	"	Time Distribution PDU
Type 3	'0'	'010'	"	Reserved for CCSDS Use
Type 4	'0'	'011'	"	Reserved for CCSDS Use
Type 5	'0'	'100'	"	Reserved for CCSDS Use
Type 6	'0'	'101'	"	Reserved for CCSDS Use
Type 7	'0'	'110'	"	Reserved for CCSDS Use
Type 8	'0'	'111'	"	Reserved for CCSDS Use
NOTE – Directives, Reports, and PLCWs can be multiplexed within the SPDU Data Field.				

3.2.8.7 VARIABLE-LENGTH SPDU

3.2.8.7.1 GENERAL

A '0' in the SPDU Format ID field identifies a variable-length SPDU data field which may contain from 0 to 15 octets of supervisory data. This form of SPDU uses bits 1 through 3 of the SPDU header to identify one of eight possible SPDU Types. Currently 2 of these 8 types are defined in the following two subsections. The remainder are reserved for future CCSDS specification.

3.2.8.7.2 TYPE 1 SPDU: DIRECTIVES/REPORTS/PLCWS

An SPDU with SPDU Type Identifier equal to '000' identifies its data field to contain from 0 to 7 (16 bit) concatenated and multiplexed protocol objects i.e., directives, reports or PLCWs. See table 3-4 for this type specification. See annex A for the formats of the type 1 SPDU data field.

3.2.8.7.3 TYPE 2 SPDU: TIME DISTRIBUTION PDU

An SPDU with SPDU Type Identifier equal to ‘001’indentifes its data field to contain from 1 to 15 bytes of time distribution supervisory data. Octet 0 of the data field contains the time distribution directive type, followed by the actual time field value (1 to 14 octets). See table 3-4 for this type specification. See annex A for the format of the type 2 SPDU data field.

4 DATA LINK LAYER

4.1 CODING AND SYNCHRONIZATION (C&S) SUBLAYER

4.1.1 FUNCTIONS

4.1.1.1 At the sending end, the C&S sublayer shall perform the following functions:

a) prepend an Attached Synchronization Marker (ASM) for each frame provided;

b) calculate and append the CRC-32 to the end of the transfer frame forming the Proximity Link Transmission Unit (PLTU);

c) pass the PLTUs to the Physical layer for transfer across the communications channel;

d) capture the time and frame sequence number associated with the egress of the trailing edge of the last bit of the ASM;

e) Provide the MAC sublayer access to the captured time and frame sequence number.

4.1.1.2 At the receiving end, the C&S sublayer shall perform the following functions:

a) delimit the PLTU from the bit stream received from the physical layer;

b) perform the error detection (CRC-32) procedure;

c) verify that the decoded PLTU is error free;

d) pass the error free transfer frames to the Frame sublayer;

e) capture the time and frame sequence number associated with the ingress of the trailing edge of the last symbol of the ASM;

f) provide the MAC sublayer access to the captured time tag and frame sequence number.

4.1.2 PROXIMITY LINK TRANSMISSION UNIT (PLTU)

4.1.2.1 PLTU Overview

4.1.2.1.1 The PLTU shall be composed of the following three fields:

a) the 24-bit ASM (mandatory—see 4.1.4);

b) the variable-length Version-3 Transfer Frame (mandatory—see 3.1);

c) the Cyclic Redundancy Code (mandatory—see 4.1.3.2).

NOTE – The size of the asynchronous PLTU shall be no greater than 2,055 octets (3 octets ASM + 2048 octets maximum transfer frame + 4 octets CRC), and shall be constrained by the size of the SDU contained within it**.** See figure 4-1.

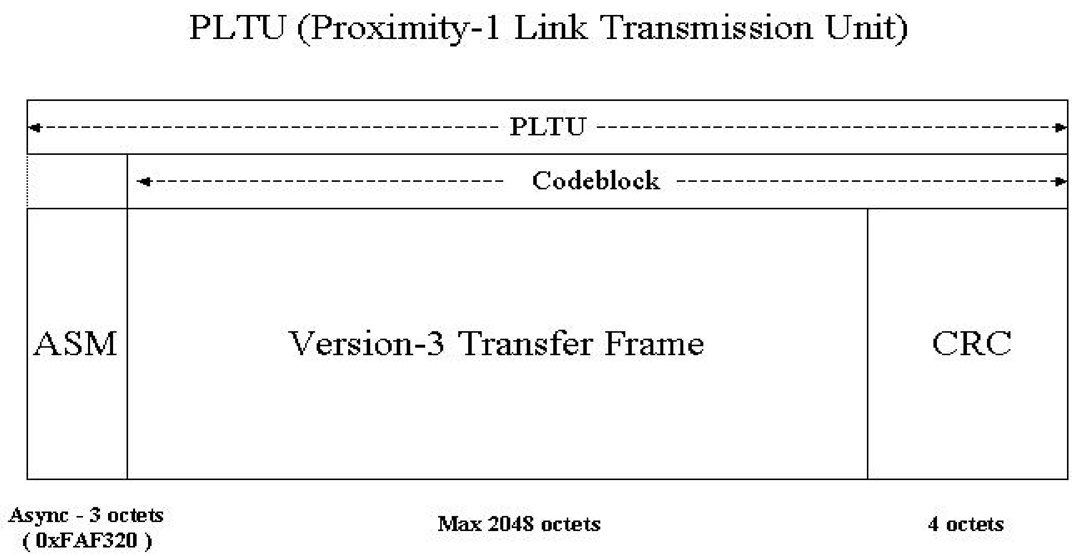


Figure 4-1: Proximity-1 Link Transmission Unit (PLTU)

4.1.2.1.2 Session establishment for half and full duplex links shall be accomplished using an asynchronous channel and data link. The data services phase shall be conducted on a synchronous channel using an asynchronous data link.

4.1.3 CODING

4.1.3.1 General

The same coding technique shall be applied to all frames for a given phase (session establishment, data services, session termination) and physical channel.

4.1.3.2 Attached Cyclic Redundancy Code

For an asynchronous link (variable-length PLTUs), an attached Cyclic Redundancy Code (CRC-32) shall be added without gap to the end of the Version-3 Transfer Frame.

NOTE – See Annex D for CRC-32 encoding and decoding procedures.

4.1.4 ATTACHED SYNCHRONIZATION MARKER

4.1.4.1 An ASM shall signal the beginning of each PLTU.

4.1.4.2 The size of the ASM shall be 24 bits in length and shall consist of the following bit pattern (in hexadecimal): FAF320.

4.1.5 C&S SUBLAYER SEND SIDE FUNCTIONALITY

4.1.5.1 C&S Sublayer Send Side Signal

The C&S sublayer shall set **PLTU_Ready** to *true* to indicate that it has a PLTU ready to send to the physical layer. **PLTU_Ready** shall be set to *false* when there is no PLTU to send.

4.1.5.2 Fill Generator

The Fill Generator shall create a fill bit pattern (it consists of the repeating Pseudo Noise sequence, 352EF853 in hexadecimal) for insertion by the C&S Sublayer into the radiation stream provided to the Physical layer. See the Proximity Physical Layer for further details on the idle pattern.

4.1.6 C&S SUBLAYER RECEIVE SIDE SIGNAL

None.

4.1.7 C&S SUBLAYER BUFFERS

4.1.7.1 Egress_Time_Capture_Buffer shall store the values of the clock and the associated frame sequence number for all proximity frames leaving the C&S sublayer when timing services occur.

4.1.7.2 Ingress_Time_Capture_Buffer shall store the values of the clock and the frame sequence number associated with the detection of the last bit of the trailing edge of the ASM of all proximity frames received by the C&S sublayer when timing services occur.

NOTE – This buffer space is required by the Proximity-1 Timing Service specified in 5.1.

4.2 FRAME SUBLAYER

4.2.1 FRAME SUBLAYER FUNCTIONS

4.2.1.1 At the sending end, the Frame sublayer (see 2.1.1) shall perform the following functions:

a) accept frames supplied by the Data Services and MAC sublayers and modify field values as necessary;

b) formulate PLCWs and status reports and incorporate them into a P-frame as required;

c) determine the order of frame transmission;

d) transfer the frames to the C&S sublayer.

4.2.1.2 At the receiving end, the Frame sublayer shall perform the following functions:

a) receive a frame from the C&S sublayer;

b) validate that the received frame is a Version-3 Transfer Frame;

c) validate that the frame should be accepted by the local transceiver based on the Spacecraft ID field and the Source/Destination ID of the Transfer Frame;

d) if the frame is a valid U-frame, route it to the data services sublayer;

e) if the frame is a valid P-frame, route the contents of the frame (SPDUs) to the MAC sublayer;

f) if the frame is a valid P-frame and contains a PLCW, route it to the Data Services sublayer.

4.2.2 FRAME SELECTION FOR OUTPUT PROCESSING AT THE SENDING END

NOTE – The Frame sublayer provides the control for formulating the frame headers and the SPDU data for transmission. The frame is delivered to the C&S sublayer to be assembled into a PLTU prior to delivery to the Physical layer.

4.2.2.1 Frame Multiplexing Process Control

4.2.2.1.1 Frames shall be generated and sent as required when the TRANSMIT parameter (6.2.2.3) is set to *on*. When the PLTU contents are ready for transmission and while TRANSMIT is *on,* the data shall be transferred to the C&S sublayer for processing.

4.2.2.1.2 When either the NEED_PLCW parameter or the NEED_STATUS_REPORT parameter is set to *true*, the required status and/or PLCW data shall be generated and inserted into a P-frame for delivery.

4.2.2.2 Ordering Frames

The following prioritization shall be observed for ordering frames:

a) first priority shall be given to a frame from the MAC queue in the MAC sublayer;

b) second priority shall be given to a PLCW/status report;

c) third priority shall be given to an Expedited frame from the Expedited Frame queue in the I/O sublayer;

d) fourth priority shall be given to a Sequence Controlled frame, first from the Sent queue if required, and then from the Sequence Controlled Frame queue in the I/O sublayer.

4.3 MEDIUM ACCESS CONTROL (MAC) SUBLAYER

4.3.1 OVERVIEW

4.3.1.1 The Medium Access Control (MAC) sublayer is responsible for the establishment and termination of each communications session. It is also responsible for any operational changes in the Physical layer configuration made during the data services phase.

4.3.1.2 Some of the operations performed by the MAC sublayer require a 'handshaking' process between the sending transceiver and the responding transceiver. This handshake is often based upon interpretation of values of the interlayer control signals, i.e., CARRIER_ACQUIRED and BIT_INLOCK_STATUS. Because of the potential for loss of an inter-transceiver control message due to corruption across the space link, MAC control activities require a 'persistence' process to ensure that the expected results of an activity are verified before any other activity is started. This process is generically defined as a Persistent activity**.**

4.3.2 PERSISTENT ACTIVITY PROCESS

4.3.2.1 General

NOTES

1 A persistent activity is a process for ensuring reliable communication between a caller and a responder using the expedited QOS while both are operating from the MAC sublayer. Because of the potential for frame loss due to corruption across the space link, these MAC control activities require a persistence process to ensure that supervisory protocol directives are received and acted upon correctly. Persistence activities may be linked in series to accomplish a task, but persistence applies to only a single activity at a time.

2 Each persistent activity consists of one or more actions (e.g., cycling the transmitter, issuing directives) followed by a WAITING_PERIOD during which a specific RESPONSE, detectable to the caller is expected. The success of the activity is determined by the detection of the expected RESPONSE within the LIFETIME of the activity. No response within this time period is deemed a failure. In either case, success or failure of the activity is communicated back to the vehicle controller.

4.3.2.1.1 The PERSISTENCE signal shall be used to notify the Frame sublayer that a persistent activity is in process and that no frames from sublayers other than the MAC should be selected for transfer.

4.3.2.1.2 Each persistent activity shall be named and shall consist of one or more actions (e.g., issuing selective directives), followed by a WAITING_PERIOD during which a specific RESPONSE, detectable by the initiating MAC, is expected.

4.3.2.1.3 Upon initiation of a persistent activity, a hold (PERSISTENCE signal is set to *true*) shall be placed upon the Frame sublayer to inhibit the selection of any frame other than a MAC frame.

4.3.2.1.4 The success or failure of the activity shall be determined by the detection of the expected RESPONSE within the activity's LIFETIME:

a) no response within the activity's LIFETIME time period shall be deemed a failure;

b) in either case, a NOTIFICATION of the activity's success or failure shall be communicated back to the vehicle controller, and the PERSISTENCE signal shall be set to *false*.

4.3.2.2 Persistence Activity Parameters

The parameters associated with a persistent activity are described below; their values vary based on the activity to be performed, and are defined per activity in the MIB.

a) ACTIVITY: the name of the persistent activity;

b) WAITING_PERIOD: the amount of time specified for the RESPONSE to be received before the process declares that the activity is to be either repeated or aborted;

c) RESPONSE: the acknowledgement by the responder that the persistent activity has been accepted;

d) NOTIFICATION: the message provided to the local vehicle controller, e.g., spacecraft C&DH by the caller and responder upon success or failure of the persistent activity;

e) LIFETIME: the time period during which the persistent activity shall be repeated until the MAC detects the expected RESPONSE.

NOTE – If the RESPONSE is not detected within the LIFETIME, the activity is aborted. The LIFETIME can be locally defined in terms of a duration or a maximum number of times this activity shall be repeated before the activity is aborted.

4.3.3 MAC CONTROL MECHANISMS

NOTE – The following mechanisms are used to coordinate and control operations between the MAC and lower sublayers.

4.3.3.1 PERSISTENCE

The PERSISTENCE signal when *true* shall set a hold on the frame selection process in the Frame sublayer, allowing only frames from the MAC sublayer to be selected for output. When *false*, no restriction applies.

4.3.3.2 MAC_FRAME_PENDING

The MAC_FRAME_PENDING parameter is provided from the MAC sublayer to the Frame sublayer. The MAC_FRAME_PENDING is set to *true* when a complete frame is loaded into the MAC Queue. MAC_FRAME_PENDING is set to *false* when the last bit of the frame is extracted from the MAC Queue.

4.3.3.3 TIME_COLLECTION

The TIME_COLLECTION variable is used to indicate the status of collecting time correlation data (time-tags and associated frame sequence numbers) during Timing Services. The Time Collection variable has three states:

a) ‘inactive’;

b) ‘collecting data’;

c) ‘collection complete’ (but not yet read out).

4.3.4 DIRECTIVE DECODER

Implementations of the Proximity-1 Space Link Protocol shall include a Directive Decoder function for processing supervisory protocol directives defined in 3.2.8 and annex A.

NOTE – The Directive Decoder is a function that decodes supervisory protocol directives received either from the local Proximity link controller or from the remote vehicle controller. The directive decoder processes the received directives setting the configuration (state and parameters) of both the Physical and Data Link layers.

4.3.5 MAC BUFFERS

4.3.5.1 Sent_Time_Buffer

The Sent_Time_Buffer shall store all of the egress clock times and associated frame sequence numbers when TIME_COLLECTION is either in the *‘collecting data’* or the *‘collection complete’* state.

4.3.5.2 Receive_Time_Buffer

The Receive_Time_Buffer shall store all of the ingress clock times and associated frame sequence numbers when TIME_COLLECTION is either in the *‘collecting data’* or the *‘collection complete’* state.

4.4 DATA SERVICES SUBLAYER

4.4.1 OVERVIEW OF FUNCTIONALITY

4.4.1.1 Send Side Functionality

The send side:

a) runs the FOP-P process;

b) processes received PLCWs;

c) acknowledges delivery of SDUs to the I/O sublayer;

d) provides frame accountability to the I/O sublayer;

e) accepts either an expedited or a sequence controlled frame from the I/O sublayer.

4.4.1.2 Receive Side Functionality

The receive side:

a) runs the FARM-P process;

b) accepts U-frames from the frame sublayer.

4.4.2 GENERAL

4.4.2.1 The Data Services sublayer shall control the order of transfer of the user data (including user-supplied directives) that are to be transmitted within the session.

4.4.2.2 The Data Services sublayer shall provide the following two grades of service:

a) Expedited service shall ensure transmission without errors of Expedited frame data in the order received;

b) Sequence Controlled service shall guarantee that data within a communication session are delivered in order without errors, gaps, or duplications.

NOTES

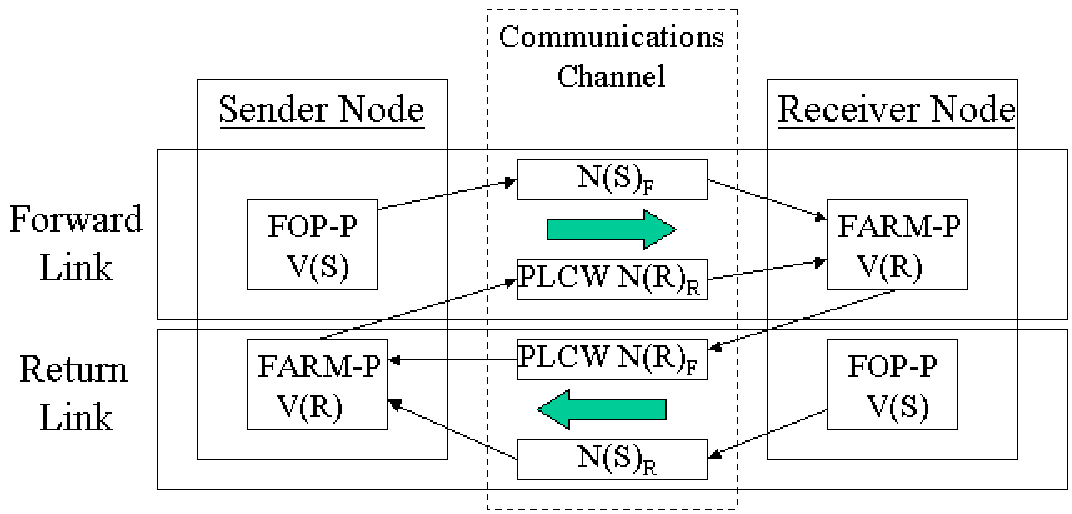
1 The guarantee of reliable data delivery by the Sequence Controlled service is constrained to a single communication session. The mechanisms provided in this specification will not eliminate duplicate data associated with the transition between the end of one session and the beginning of the next. Elimination of this problem is left to the controlling data system.

2 These services are provided by the Communication Operation Procedure for Proximity links (COP-P). The Data Services sending operations are described in 7.1, and the Data Services receiving operations are described in 7.2.

4.4.3 OVERVIEW OF THE COP-P PROTOCOL

The COP-P protocol is used with one Sender Node, one Receiver Node, and a direct link between them. The Sender delivers frames to the Receiver. The Receiver accepts all valid Expedited frames, and valid Sequence Controlled frames that arrive in sequence. The Receiver provides feedback to the Sender in the form of a Proximity Link Control Word (PLCW). The Sender uses this feedback to retransmit Sequence Controlled frames when necessary. Expedited Frames are never retransmitted.

Concurrent bi-directional data transfer is a capability. In this case, each node has both sender and receiver functionality as shown in figure 4-2, COP-P Process.



Notes:

1 The User data frames (U-frames) in the forward link contain the frame sequence number $N(S)_F$. The U-frames in the return link contain the frame sequence number $N(S)_R$.

2 The PLCW Supervisory protocol frames (P-frames) in the forward link are reporting return link progress and contain the frame sequence number $N(R)_R$. The P-frames in the return link are reporting forward link progress and contain the frame sequence number, $N(R)_F$.

Figure 4-2: COP-P Process

Both the Sender Node and the Receiver Node contain two types of procedures: the send side procedures i.e., the Frame Operations Procedures-Proximity (FOP-P) and the receive side procedures, i.e., the Frame Acceptance and Reporting Mechanism-Proximity (FARM-P).

The FOP-P drives the Expedited and Sequence Controlled services. It is responsible for ordering and multiplexing the user supplied data and maintaining synchronization with the FARM-P. It initiates a retransmission when required. If a valid PLCW is not received in a reasonable time period (defined by the MIB parameter, Synch_Timeout), the Sender Node's FOP-P notifies the local controller that it is not synchronized with the Receiver Node's FARM-P. It is the responsibility of the local controller to decide how synchronization will be re-established, if the MIB parameter, Resync_Local equals *false.* Otherwise, the Sender Node's FOP-P forces synchronization by sending the SET V(R) directive.

The FARM-P is data-driven, i.e., it simply reacts to what it receives from the FOP-P and provides appropriate feedback via the PLCW. The FARM-P utilizes the services of the Coding and Synchronization sublayer to verify that the frame was received error free. It depends upon the Frame sublayer to verify that the frame is a valid Version 3 CCSDS frame and that it should be accepted for processing by the Data Services sublayer.

The FOP-P and FARM-P procedures control both Expedited and Sequence Controlled qualities of service.

4.4.4 INTERFACE TO HIGHER SUBLAYER

FOP-P provides V(S) and VE(S) to the I/O Sublayer for every Sequence Controlled frame it numbers.

4.5 I/O INTERFACE SUBLAYER

4.5.1 FUNCTIONS

4.5.1.1 Upon input, the I/O interface sublayer shall:

a) Accept for transfer the data for which the user specifies:

   1) the required QOS;

   2) the output port ID;

   3) PDU type (user data or protocol directives);

   4) the frame data field construction rules to build a Version-3 Transfer Frame (see 3.2.2.5);

   5) Remote_Spacecraft_ID;

   6) PCID;

   7) Source-or-Destination Identifier.

b) Using the value of the MIB parameter, Maximum_Packet_Size, organize the received data (including metadata) to form the Frame Data Unit and the Transfer Frame Header (frame sequence number shall be set to null).

NOTE – This process will determine how to integrate the received packets into the frames. It includes segmenting packets (asynchronous data links) when their size is too large to fit within the maximum allowed frame size.

c) Notify the user when an Expedited SDU is radiated.

d) Notify the user when a Sequence Controlled SDU has been successfully transferred across the communication channel.

4.5.1.2 The I/O interface sublayer shall output received and accepted SDUs:

a) receive U-frames accepted via the lower sublayers;

b) assemble received segments into packets and verify that the packet is complete;

c) deliver only complete packets to the user (length of the rebuild packet must match packet length field), and discard incomplete packets;

d) deliver the packets/user-defined data via the specified output port ID in the U-frame header.

4.5.2 INTERFACE TO THE LOWER SUBLAYERS

4.5.2.1 The I/O interface sublayer shall pass the service data units that require the Sequence Controlled service via the Sequence Controlled queue, and shall pass those for the Expedited service via the Expedited queue.

4.5.2.2 This sublayer shall provide two queues (Expedited Queue and Sequence Controlled Queue) for the received U-frames capable of supporting the maximum data rate expected using the communications channel with that transceiver.

4.5.2.3 For Sequence Controlled Service, the I/O Sublayer maintains an association between each SDU provided to the Data Services Sublayer and the frame sequence number of the frame which contains the last octet of that SDU.

4.5.2.4 For Sequence Controlled Service, the I/O Sublayer evaluates NN(R) to validate that a complete SDU was received from the Data Services Sublayer, and notifies the user when acknowledged transfer of the SDU has been accomplished.

4.5.3 I/O SUBLAYER QUEUES AND ASSOCIATED CONTROL SIGNALS

a) The *Sequence Controlled Frame queue* contains Sequence Controlled frames that are ready for transmission but have not yet been sent. This name is abbreviated to *SEQ Queue* in the COP-P Sender state table. While any data units are stored within this queue, Sequence_Frame_Available shall be *true*; otherwise, it shall be *false*.

b) The *Expedited Frame queue* contains Expedited frames that are ready for transmission but have not yet been sent. This name is abbreviated to *EXP Queue* in the COP-P Sender state table. While any data units are stored within this queue, Expedited_Frame_Available shall be *true;* otherwise, it shall be *false*.

c) When the Data Services Sublayer extracts a frame from either queue, that frame is permanently removed from the queue, and the appropriate frame available parameter is re-evaluated.

NOTE – The local directive, Clear Queue (Queue Type) allows for the clearing of frames from either the SEQ or EXP Queue.

5 PROXIMITY-1 TIMING SERVICES

5.1 COUPLED NON-COHERENT PROXIMITY TIMING SERVICE

Timing Services shall be required for Proximity operations in order to provide the following three capabilities:

a) on-board proximity clock correlation between proximity nodes;

b) Universal Time Code (UTC) time transfer to a proximity node;

c) coupled non-coherent time-derived ranging measurements between proximity nodes.

All three of these capabilities require that MODE is active and the transceiver is operating in data services. Timing Services can occur in full duplex, half duplex, or simplex operations. Note that timing services can occur concurrently with other data-taking activities. The method utilized to carry out the timing services specified in 5.2.

5.2 PROXIMITY TIME CORRELATION

NOTE – The same time-stamp capture method is used for the basis of all three time services capabilities. The method requires that both the initiating and recipient transceiver shall have the capability of time tagging the trailing edge of the last bit of the Attached Synchronization Marker of every incoming and every outgoing proximity frame.

5.2.1 TIME STAMP CAPTURE METHOD

The time stamp capture method shall be composed of the following steps:

a) The vehicle controller shall issue a local time-stamp directive to the initiating transceiver, instructing it to capture its local time reference and associated frame sequence numbers over a commanded interval of frames. Upon receipt of this directive, the MAC shall set the Time_Collection variable from *inactive* to *'collecting data',* indicating that time collection has started.

b) The Initiating transceiver shall build and transmit the SET CONTROL PARAMETERS (*Time Sample*) directive. Upon egress of each frame during the commanded interval (based upon the value of Time Sample), the initiating transceiver shall capture the time and frame sequence number of every proximity frame being radiated. The application processes, which use the collected data, will also require information about any internal signal path delays associated with the radiation process. Once the commanded interval has been reached (the prescribed number of frame time tags have been captured), the MAC shall set the Time_Collection variable to '*collection complete'*, indicating that those times and sequence numbers are available for transfer. Coincidently upon ingress of each of these frames, the recipient transceiver shall identify and decode the directive and capture the time, and frame sequence number, of every proximity frame received over the commanded interval. It also keeps track of any internal signal path delays in the process. Upon readout of the collected data set, Time_Collection is set *inactive*.

c) When the Time_Collection process is completed, both the initiating and remote transceivers shall transfer their captured times and the associated frame sequence numbers of every outgoing and every incoming Proximity-1 frame to their respective vehicle controllers.

d) The vehicle controller (CDS) shall create a proximity time correlation packet consisting of time tags it received from its local transceiver, i.e., the series of points (frame time tag, frame sequence number) collected over the commanded interval and their internal signal path delays for their specific configuration. Note that:

   1) these points represent a series of either all ingress or all egress values;

   2) the internal delays have coding and rate components;

   3) these time correlation packets need to be processed together;

   4) simultaneous collections in both directions would increase the accuracy of the processing.

e) By exchanging time correlation packets, either node can compute the correlation between the two proximity clocks.

NOTE – The time capture event is the trailing edge of the last bit of the Attached Synchronization Marker upon ingress and egress. The time code format is provided in reference [8], i.e., the unsegmented time code of 4 bytes of course time (> 1 sec) and 3 bytes of fine time (< 1 sec). See figure 5-1, Proximity Time Tagging and Time Correlation.

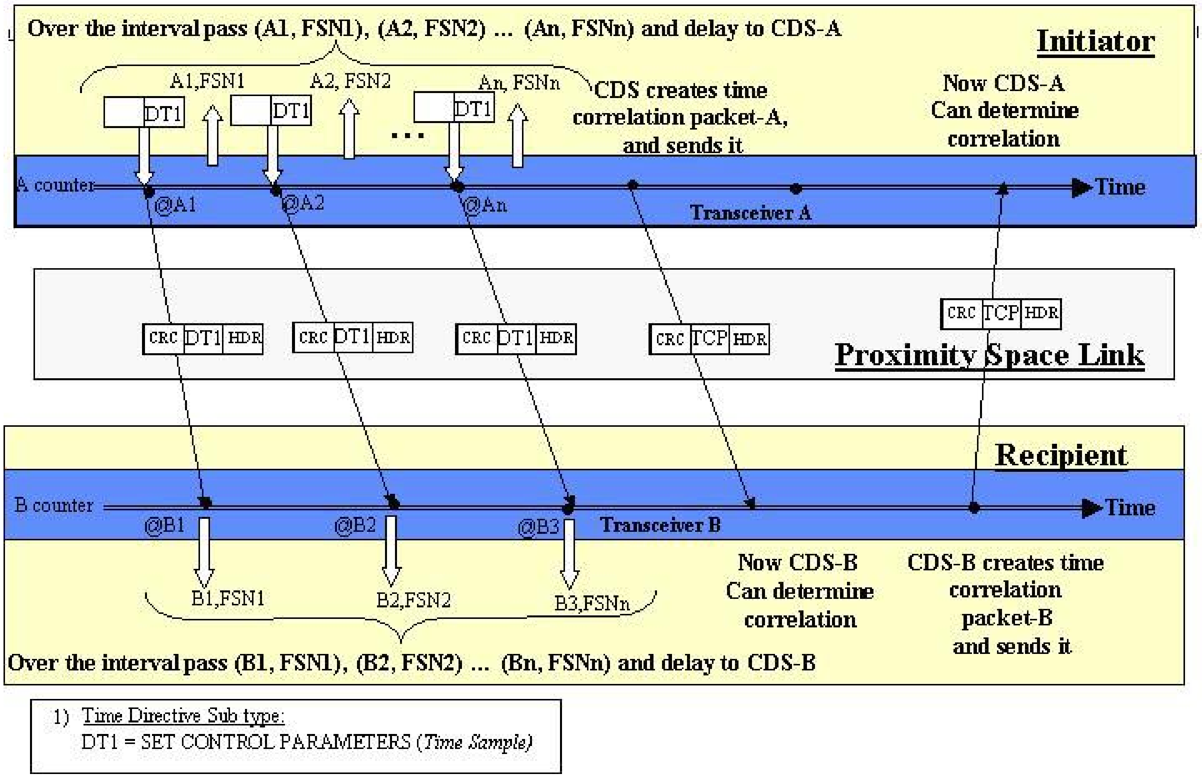


Figure 5-1: Proximity Time Tagging and Time Correlation

5.2.2 TRANSFERRING UTC TO A REMOTE ASSET

In order to transfer a UTC equivalent time to a remote asset, the initiator must know the correlation between the initator's clock and the recipient's clock. It is also assumed that the initiator maintains a correlation between UTC and its local proximity clock. The method for transferring UTC to a remote asset shall consist of the following steps:

a) As soon as possible after a proximity time correlation between the initiator and recipient is completed, the initiator shall build and transmit the UTC TIME TRANSFER directive over the proximity link. This directive contains the correlation between UTC and the recipient's clock.

b) The recipient transceiver shall decode the directive and transfer the contents of the directive (UTC to local proximity clock correlation) to its vehicle controller.

c) The recipient vehicle controller shall apply the correlation in order to either project future UTC values, or correct past UTC values.

NOTE – The Time Code format of all proximity clocks including the representation of UTC shall follow the CCSDS unsegmented time code of 4 bytes of course time (> 1sec) and 3 bytes of fine time (< 1 sec). See reference [8]. See figure 5-2, Transferring UTC to a Remote Asset.

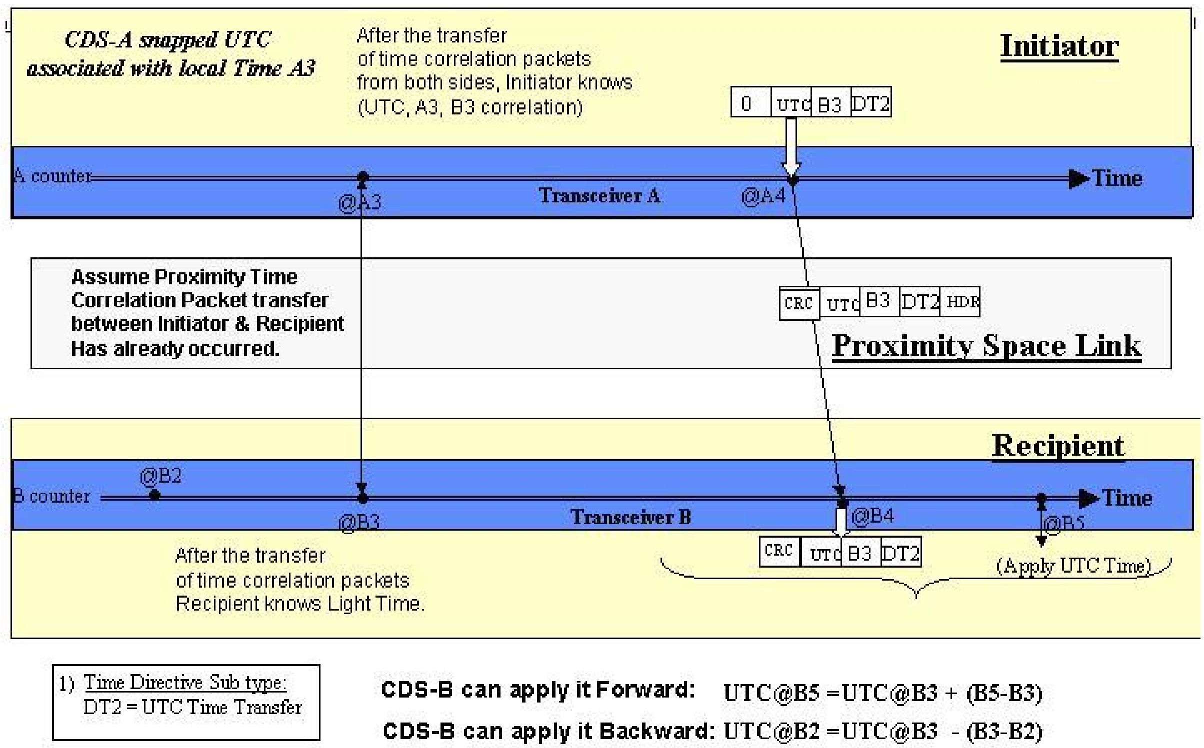


Figure 5-2: Transferring UTC to a Remote Asset

6 DATA SERVICES OPERATIONS

6.1 OVERVIEW

Section 6 consists of a comprehensive set of state tables, state variable descriptions, and state diagrams for Proximity-1 data services operations. Table 6-1 provides a roadmap to help navigate through this section.

Table 6-1: Proximity-1 Data Services Operations Roadmap

Operations	Applicable Proximity-1 State Tables	Applicable State Transition Tables	Applicable State Transition Diagram
Full Duplex	Tables 6-2, 6-3	Session Establishment and Data Services: Table 6-8 Comm Change: Table 6-9 Session Termination: Table 6-10	Full Duplex Operations: Figure 6-1
Half Duplex	Tables 6-2, 6-4	Session Establishment and Data Services: Table 6-11 Comm Change: Table 6-12 Session Termination: Table 6-13	Half Duplex Operations: Figure 6-2
Simplex	Tables 6-2, 6-5	Simplex State Transition Table: Table 6-14	Simplex Operations: Figure 6-3

6.2 PROXIMITY-1 STATE TABLES

6.2.1 OVERVIEW

The operating states for the Proximity-1 protocol are shown in tables 6-2 through 6-5. These states are dependent on four state-controlling variables: DUPLEX, MODE, TRANSMIT (T), and SUB-STATE (SS). The Receive and Send State Descriptions consist of the values *off,* *on, synchronous* (data link) and *asynchronous* (data link). See 1.5.1.3 for definitions. The events that affect state status are described in 6.3. State Transition Tables are provided in 6.4.

Table 6-2: States Independent of the DUPLEX Parameter

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	DESCRIPTION
S1	*Inactive*	*off*	*off*	inactive	N/A	0	The only actions that are permitted in state S1 are those in response to local directives. In this state the Data Services operational variables and MIB parameter values can be modified and their status read via local directives from the local controller. When the protocol enters this state the variables identified in Table 6-7 are initialized. The Local SET MODE (*initialize*) directive will force entry to this state and will initialize the selected operational variables listed in Table 6-6.
S2	*Waiting for HAIL*	*on*	*off*	*connecting-L*	*N/A*	*0*	In this state, receiving operations are enabled. FARM-P operations are enabled but only for processing received supervisory directives i.e., transfer frame header PDU TYPE ID = ‘1’. Note that only receiving operations are enabled so that transmission is not permitted.
S31	*Start Hail Action*	*off*	*async*	*connecting-T*	*on*	*1*	In this state the HAIL Activity starts with the radiation of the carrier signal.
S32	*Send Hail Acquisition*	*off*	*async*	*connecting-T*	*on*	*2*	In this state the idle pattern is radiated to achieve bit lock with the hailed remote unit.
S33	*Send Hail Directives*	*off*	*async*	*connecting-T*	*on*	*3*	In this state the HAIL directives (SET_TRANSMITTER_PARAMETERS and SET_RECEIVER_PARAMETERS) are radiated to initiate a session with the hailed remote unit.
S34	*Send Hail Tail*	*off*	*async*	*connecting-T*	*on*	*4*	In this state the idle pattern is radiated to allow the HAIL directives to be received and processed through the decoding chain of the hailed remote unit.

Table 6-3: States When DUPLEX = *Full*

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	DESCRIPTION
S35	*Wait for Hail Response*	*on*	*async*	*connecting-T*	*on*	5	In this state the transceiver awaits a response from the hailed remote unit.
S41	*Radiate Carrier Only*	*on*	*sync*	*active*	*on*	*1*	In this state the receiver is on and ready to process all received data while the transmission process is started with carrier radiation only.
S42	*Radiate Acquisition Idle*	*on*	*sync*	*active*	*on*	*2*	In this state the receiver is on and processing all received data while the transmission process is trying to achieve bit lock with a potential partnered transceiver.
S40	*Data services*	*on*	*sync*	*active*	*on*	*0*	In this state data transfer services controlled by the COP-P protocol are conducted with a partnered transceiver.
S48	*Comm_Change*	*on*	*sync*	*active*	*on*	*6*	This state is involved with the protocol actions required to perform a data rate or frequency change with a partnered transceiver. This state contains numerous sub-states whose transitions are described in section 6.3.1.2. Full Duplex Comm Change State Table.
S45	*Terminating Tail*	*on*	*sync*	*active*	*on*	*4*	In this state the receiver is on and processing all received data while the transmission process is terminating. See table 6-9.

Table 6-4: States When DUPLEX = *Half*

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	DESCRIPTION
S36	*Wait for Hail Response*	*on*	*off*	*connecting-T*	*off*	5	In this state the transceiver awaits a response from the called remote unit.
S51	*Radiate Carrier Only*	*off*	*sync*	*active*	*on*	*1*	In this state the transmission process is started with carrier radiation only.
S52	*Radiate Acquisition Idle*	*off*	*sync*	*active*	*on*	*2*	In this state the transmission process is trying to achieve bit lock with a potential partnered transceiver.
S50	*Data Services (send)*	*off*	*sync*	*active*	*on*	*0*	In this state the user data transmission process functions.
S54	*Terminate Reply*	*off*	*sync*	*active*	*on*	*3*	In this state the transmission process is sending the termination directive.
S55	*Tail Before Quit*	*off*	*sync*	*active*	*on*	*7*	In this state the transmission process is sending the terminating tail sequence bits.
S56	*Token Pass or Comm Change*	*off*	*sync*	*active*	*on*	*6*	In this state the transmission process is sending either a Token Pass or the Comm_Change directive.
S58	*Tail before Switch*	*off*	*sync*	*active*	*on*	*4*	In this state the transmission process is sending the terminating tail sequence bits.
S60	*Data Services (receive)*	*on*	*sync*	*active*	*off*	*0*	In this state the receiver is processing received data.
S61	*Awaiting First Frame*	*on*	*sync*	*active*	*off*	*1*	In this state the receiver is on, waiting receipt of the first frame for processing.
S62	*Wait for Carrier*	*on*	*sync*	*active*	*off*	*2*	In this state the receiver is on, waiting for the Carrier_Acquired signal to transition to *true*.

Table 6-5: States When DUPLEX = *Simplex*

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	DESCRIPTION
S71	Simplex Transmit	*off*	*on*	*active*	*on*	*0*	In this state only the transmission operations are enabled while receiving operations are inhibited.
S72	Simplex Receive	*on*	*off*	*active*	*off*	*0*	In this state only the receiving operations are enabled while transmission operations are inhibited.

6.2.2 STATE CONTROL VARIABLES

NOTE – These variables are contained within the Proximity-1 State Tables: MODE, DUPLEX, TRANSMIT, and SUB-STATE.

6.2.2.1 MODE

The MODE parameter shall provide control information for operations within the Data Link layer, and control operations within the Physical layer. The allowable states of MODE (set via the local SET MODE directive) are as follows:

a) ***inactive***: In the Inactive state the transceiver's transmitter and receiver shall both be turned off.

b) ***connecting-T***: In the Physical layer, the Connecting-Transmit state in full duplex shall dictate that the receiver (sequentially in half duplex) and transmitter are powered on and enabled to process received frames, and that the transmitter is enabled for asynchronous channel operations. (In half duplex, only the transmitter is powered on.) Hail Activity shall be conducted while Mode is connecting-T.

c) ***connecting-L***: In the Connecting-Listen state, the receiver shall be powered on and enabled to process received frames while the transmitter is turned off.

d) ***active***: In the Active state the receiver shall be powered on and enabled to process received frames; the transmitter shall be enabled for synchronous channel operations responding to the control of the TRANSMIT parameter**.**

NOTE – The Local INITIALIZE MODE directive puts MODE into the inactive state, and initializes the variables described in table 6-6 as well.

6.2.2.2 DUPLEX

DUPLEX shall identify the physical channel communications characteristics so that the protocol can perform within the transceiver's operational constraints. The allowable values of DUPLEX (set via the local SET DUPLEX directive) shall be:

a) ***full*****:** both the receiver and transmitter shall be simultaneously enabled;

b) ***half*****:** operation switches between receiving and transmitting within a communications session, with only the receiver or the transmitter enabled at one time;

c) ***simplex*****:** either the transmitter or the receiver shall be enabled at any given time (i.e., not both), depending upon the directionality of the data flow.

6.2.2.3 TRANSMIT

The TRANSMIT parameter shall be used to control Physical layer operations when MODE is not equal to *inactive*. This parameter has three states, as follows:

a) ***off***: the Physical layer shall be signaled to transition the transmitter to *off* and transition the receiver to *on.*

b) ***on***: the Physical layer shall be signaled to transition the transmitter to *on*, and during half duplex or simplex operation to transition the receiver to *off.*

c) ***standby***: the Physical layer shall be signaled to transition the transmitter to *off* and to transition the receiver to *off.*

6.2.2.4 SS (SUB-STATE)

The SS variable shall be used to keep track of sequencing through Proximity-1 states in response to events.

6.2.3 OPERATIONAL CONTROL VARIABLES

6.2.3.1 X (Session Termination)

X (Session Termination) shall be used to track the sub-states of the full and half duplex session termination process. In half duplex, it shall be shared between receive and transmit functionality. The values and definitions of the states of X are as follows:

a) X=0: Bi-directional data passing in progress. Neither transceiver has declared that it is out of data to send. Used in full and half duplex.

b) X=1: Local transceiver informed that there is locally no more data to send, i.e., Local_No_More_Data **(**LNMD). Used in half duplex only.

c) X=2: Local transceiver has received the LNMD indicator and is sending the Remote_No_More_Data (RNMD) directive to the remote transceiver. When an RNMD directive is received in this state, the session is terminated. Used in full and half duplex.

d) X=3: Local transceiver has data to send and it has received an RNMD directive from the remote transceiver. Used in half duplex only.

e) X=4: Local transceiver informed that it has no more data to send, and it sends a RNMD directive to the remote transceiver. Used in full and half duplex.

f) X=5: Both local and remote transceivers have no more data to send. Once the RNMD directive is sent, the session is terminated and X is reset to 0. Used in full- and half duplex.

6.2.3.2 Y (Comm Change)

Y (Comm Change) shall be used to track the sub-states during the commanding of a physical layer communications change. In half duplex, it shall be set on the transmit side and reset on the receive side. Valid values for Y in both full and half duplex shall be: 0 through 3. The values and the states of Y are as follows:

a) Y=0: No Comm Change in progress.

b) Y=1: Local directive received to initiate the Comm Change (LCCD).

c) Y=2: Comm Change Directive being sent across the proximity link.

d) Y=3: Comm Change Directive sent, and now waiting for the Comm_Change acknowledgement.

e) Y=4: Receive the Remote Comm Change Directive (RCCD). Used only in Full duplex.

f) Y=5: Act upon the remote Comm Change Directive received (RCCD). Used only in Full duplex.

6.2.3.3 Z (Bit In Lock Status)

Z (Bit In Lock Status) shall be used during a physical layer communications change to track non-deterministic events within State 48, as follows:

a) Z=0: Bit_In_Lock_Status has not transitioned to *false*.

b) Z=1: Bit_In_Lock_Status has transitioned to *false*.

6.2.3.4 M(odulation)

M(odulation) is an interface variable with the Physical Layer which shall control the modulation of the transmitted carrier. When Modulation=*true*(on), the data are modulated onto the radiated carrier; when Modulation=*false*(off), the radiated output is not modulated (i.e., carrier only).

6.2.3.5 P(ersistence)

P(ersistence) shall be used to enhance the reliability of the communication for a specific action. While persistence is set to on, frames containing data and PLCWs shall be prevented from being loaded into the output First In First Out (FIFO), and a waiting period shall be established in which a specific response event is anticipated. If the event occurs, then persistence shall be set off and a new state is entered. If the event does not occur within the waiting period, the series of actions being performed in this state shall be repeated until the lifetime of the persistence action is reached.

6.2.3.6 NEED_PLCW

NEED_PLCW shall be used in the data selection for output process to determine if a PLCW should be sent. This variable shall be set true:

a) at initialization;

b) by events in the state transition processes;

c) by PLCW count down timer; and

d) by actions within the COP-P.

This variable shall be set *false* when a PLCW is selected for output.

6.2.3.7 REMOTE SCID BUFFER

REMOTE SCID BUFFER holds the value of the spacecraft ID that shall be used in all frames whose Source/Destination Flag is set to 'destination'.

6.2.3.8 COMMUNICATION VALUES BUFFER

COMMUNICATION VALUES BUFFER shall be used to hold the communication values for the HAIL and Change Communications Directives and operations.

6.2.3.9 RECEIVING_SCID_BUFFER

RECEIVING_SCID_BUFFER shall be used in the frame acceptance process to compare a received SCID value with that held within this buffer. This buffer may be loaded by a directive from the local spacecraft controller, or it may be loaded from the first received frame.

6.2.4 MIB PARAMETERS

6.2.4.1 Local_Spacecraft_ID

Local_Spacecraft_ID shall contain the value of the spacecraft ID for this Protocol Unit (this local spacecraft).

6.2.4.2 Test_Source

The Test_Source parameter shall be used to determine whether the received frames whose Source/Destination Flags are set to 'S*ource*' shall be tested for acceptance. Test_Source=false means no test shall be performed. Test Source=true means a test shall be performed if the RECEIVING_SCID_BUFFER is non-blank. When the RECEIVING_SCID_BUFFER is blank and Test_Source is true, the value of the SCID field in the header of the first received frame whose Source/Destination flag is 'S*ource*' shall be loaded into RECEIVING_SCID_BUFFER.

6.2.4.3 Carrier_Only_Duration

Carrier_Only_Duration represents the time that shall be used to radiate an unmodulated carrier at the beginning of a transmission.

6.2.4.4 Acquisition_Idle_Duration

Acquisition_Idle_Duration represents the time that shall be used to radiate the idle sequence pattern at the beginning of a transmission to enable the receiving transponder to achieve bit synchronization and decoder lock.

6.2.4.5 Tail_Idle_Duration

Tail_Idle_Duration represents the time that shall be used to radiate the idle sequence pattern at the end of a transmission to enable the receiving transponder to process the last transmitted frame (i.e., push the data through the decoders).

6.2.4.6 Carrier_Loss_Timer_Underflow

Carrier_Loss_Timer_Underflow represents the time that shall be used to determine if the loss of carrier means that the responding spacecraft is no longer in view, and that the session should be terminated.

6.2.4.7 Hail_Waiting_Period

Hail_Waiting_Period represents the time that the initiating transponder will wait for a response to the HAIL.

6.2.4.8 Send_Duration

Send_Duration represents the maximum time that the half duplex transmitter shall transmit data before it relinquishes the Token (transfers to receive).

6.2.4.9 Receive_Duration

Receive_Duration represents the maximum time that the half duplex receiver is anticipating that the transmitting side shall be transmitting.

6.2.4.10 PLCW_Repeat

PLCW_Repeat represents the maximum transmission time between PLCWs, even if PLCWs are not required for Sequence Control operations. A zero value represents an infinite time period.

6.3 ELEMENTS AND EVENTS THAT AFFECT STATE STATUS

NOTE – The Interval_Clock applies to all timers. It is a frequency (e.g., 100 Hz) that is used for interval timing. It is recommended that the output bit clock could be substituted for this clock for counting down the acquisition and tail sequence periods.

6.3.1 WAIT TIMER (WT) AND ITS ASSOCIATED EVENTS

NOTE – The Wait Timer is a down counter. The count-down is enabled only when the timer is non-zero.

The values loaded into the timer shall represent a desired time value consistent with the Interval Clock frequency. The timer shall be loaded with the required MIB parameter value (see tables 6-2 through 6-5), and shall be counted down using the Interval_Clock. The value in the timer shall be counted down until underflow.

NOTES

1 The timer may be reset to zero by specific actions identified in the state transition tables.

2 The Wait Timer event (WT=1) occurs when the value in the timer/counter is equal to 1. Subsequently, the timer then underflows to zero, which is the inactive state for the timer.

6.3.2 CARRIER_LOSS_TIMER AND ASSOCIATED EVENTS

The CARRIER_LOSS_TIMER:

a) Shall be used to terminate the session if communication from the remote transceiver is lost for an extended period (defined in the MIB) after the data services phase has started.

b) Shall be a down counter that is driven by the Interval Clock. The countdown is enabled only when the timer is non-zero. The values loaded into the timer shall represent a desired time value consistent with the Interval Clock's frequency.

c) Shall be loaded with the value contained in the MIB parameter Carrier_Loss_Timer_Underflow when the following conditions are simultaneously satisfied:

   1) the Carrier Loss Timer value is *0*;

   2) Mode = *Active*;

   3) either [DUPLEX = *full* or (Duplex = *half* .AND. TRANSMIT = *Standby*)].

d) Shall be reset to zero when the Carrier_Acquired (Physical_Layer) signal is *true* and when DUPLEX = *half* .AND. TRANSMIT=*on*.

NOTE – The Carrier_Loss_Timer event occurs when the value in the timer/counter is equal to 1, which indicates that the Carrier signal has not been received for the specified period.

6.3.3 OUTPUT FIFO

NOTE – The Output FIFO is a FIFO cache for the storage of bits that are serially output to the Physical Layer for radiation.

The FIFO shall be filled with data per the specification defined in table 6-15. The data in the FIFO shall be serially shifted out using the output clock provided by the Physical Layer, which is consistent with the physical link data rate. The 'Output FIFO =empty' signals that no data is contained within the FIFO, and more data must be put into the FIFO to keep the output bit stream synchronous.

6.3.4 NO_FRAMES_PENDING

The No_Frames_Pending Event shall occur when the Output FIFO becomes empty and there are no frames selectable for output.

6.3.5 PLCW TIMER AND ASSOCIATED EVENTS

The PLCW Timer shall be used periodically to request the issuance of a PLCW. The PLCW Timer is a down counter that is driven by the Interval_Clock. When the PLCW Timer=1, the NEED_PLCW variable shall be set *true*. The Timer shall be loaded with the value in the PLCW_Repeat MIB parameter whenever a PLCW is transmitted (see the FARM-P State Table contained in subsection 7.2.1).

NOTE – The PLCW Timer does not appear in the state transition tables.

6.3.6 DIRECTIVES

6.3.6.1 Local Directives

NOTE – Local directives are sent internally, i.e., not across the Proximity link.

6.3.6.1.1 SET MODE

a) **Connecting-L:** This value shall set the MODE variable to *Connecting-Listen.*

b) **Connecting-T:** This value shall set the MODE variable to *Connecting-Transmit* which starts the HAIL activity.

c) **Inactive**: This value shall set the MODE variable to Inactive.

d) **Active:** This value shall set the MODE variable to Active. It is typically used for simplex operations.

6.3.6.1.2 Initialize MODE

This directive shall put MODE into the inactive state, and shall initialize the COP-P variables described in table 6-6.

6.3.6.1.3 Local COMM_CHANGE (LCCD)

This directive consists of the functionality identified in the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS directives, which shall initiate a change in the communication channel data rate or frequency

NOTE – The Remote Comm Change Directive (RCCD) consists of these two directives and is sent across the proximity link.

6.3.6.1.4 Load Communications Value Buffer

This directive shall load the values for the remote transmitter and receiver associated with either the HAIL ,COMM_CHANGE, or half duplex receiver/transmitter switching activities.

6.3.6.1.5 Local_No_More_Data (LNMD)

This directive shall inform the Protocol Controller that the local user has no more data to send. This directive shall initiate the session termination process.

6.3.6.1.6 Set Duplex

This directive shall configure the local transmitter and/or receiver for either full duplex, half duplex, or simplex operations.

6.3.6.1.7 Read Status

This directive shall selectively read the local status registers and buffer (including timing services) within the transceiver.

6.3.6.2 Remote Directives

NOTE – Remote directives are sent over the Proximity link. HAIL and COMM_CHANGE directives (as described below) are used for both the hail directive and for physical layer communication changes.

6.3.6.2.1 SET TRANSMITTER PARAMTERS

SET TRANSMITTER PARAMETERS shall be used to set the transmission parameters that control the data rate, encoding, modulation, and frequency in the transceiver receiving the directive. Upon receipt, this directive shall set the receiver’s MODE variable to ‘Active’.

NOTE – This directive is formulated using the values contained in the sender’s Communication Value Buffer. See annex A for a complete definition.

6.3.6.2.2 SET RECEIVER PARAMETERS

SET RECEIVER PARAMETERS shall be used to set the receiver parameters that control the data rate, decoding, modulation, and frequency in the transceiver receiving the directive. Upon receipt this directive shall set the receiver's MODE variable to 'Active'.

NOTE – This directive is formulated using the values contained in sender's Communication Value Buffer. See annex A for a complete definition.

6.3.6.2.3 SET CONTROL PARAMETERS

NOTE – This directive consists of 3 independent fields. See annex A for a complete definition.

SET CONTROL PARAMETERS shall be used to provide transmit operational control information during a session. It includes the following fields:

a) **Token Field**: Notifies the receiver that the sender is relinquishing the 'Send Token' and is switching to receive.

b) **Remote_No_More_Data Field (RNMD):** When this field contains a 'one' it shall notify the recipient that the sending Protocol Unit has no more data to send, and that the session may be terminated when the recipient also has no more data to send.

c) **Time Sample Field:** When this field is non-zero it shall notify the recipient to capture the time and sequence number for the next n frames received (where 'n' is the value (number of frames) contained within the Time Sample Field).

6.3.7 INITIALIZED COP-P VARIABLES (Per the local SET INITIALIZE MODE Directive)

NOTE – These variables are per the local SET INITIALIZE MODE Directive. See table 6-6.

Table 6-6: COP-P Variable Initialization Table

Variables	Value
Need PLCW/Need Status	*True*
V(R),VV(S),V(S),VE(S),NN(R)	*0*
Carrier Loss Timer	*0*
Expedited Frame Counter	*0*
R(R),RR(R)	*False*

6.3.8 INITIALIZED PROXIMITY-1 CONTROL VARIABLES (WHENEVER MODE = *inactive*)

NOTE – These variables are used whenever MODE = *inactive*. See table 6-7.

Table 6-7: Proximity-1 Control Variable Initialization Table

Variables	Value
TRANSMIT, Modulation, Persistence	*off*
SS, X, Y and Z	*0*
Wait Timer, Carrier_Loss_Timer,PLCW_Timer	*0*

6.4 STATE TRANSITION TABLES AND DIAGRAMS

6.4.1 OVERVIEW

The following subsections contain State Transition Tables and State Transition Diagrams which should be read in conjunction with one another for completeness.

The State Transition Diagrams are intended to illustrate transitions from one state to another, and the events that trigger them. States are shown in boxes. Events that cause transitions from one state to a resultant state are given in italic text beside arrows that indicate the transition between states.

States, which have a descriptive title, are assigned the letter S and a number that corresponds with the numbers in the two left hand columns in the State Transition Tables. These two columns indicate the starting state and the resultant state of a transition, and the remaining columns describe the event causing the transition, as well as any additional actions (in addition to what is described in tables 6-2 through 6-5) that take place as a result of entering that state.

The diagrams do not show all possible states for reasons of simplicity and clarity. For completeness, the State Transition Tables and accompanying text contain a description of all states and events not included in the diagrams.

6.4.2 FULL DUPLEX OPERATIONS

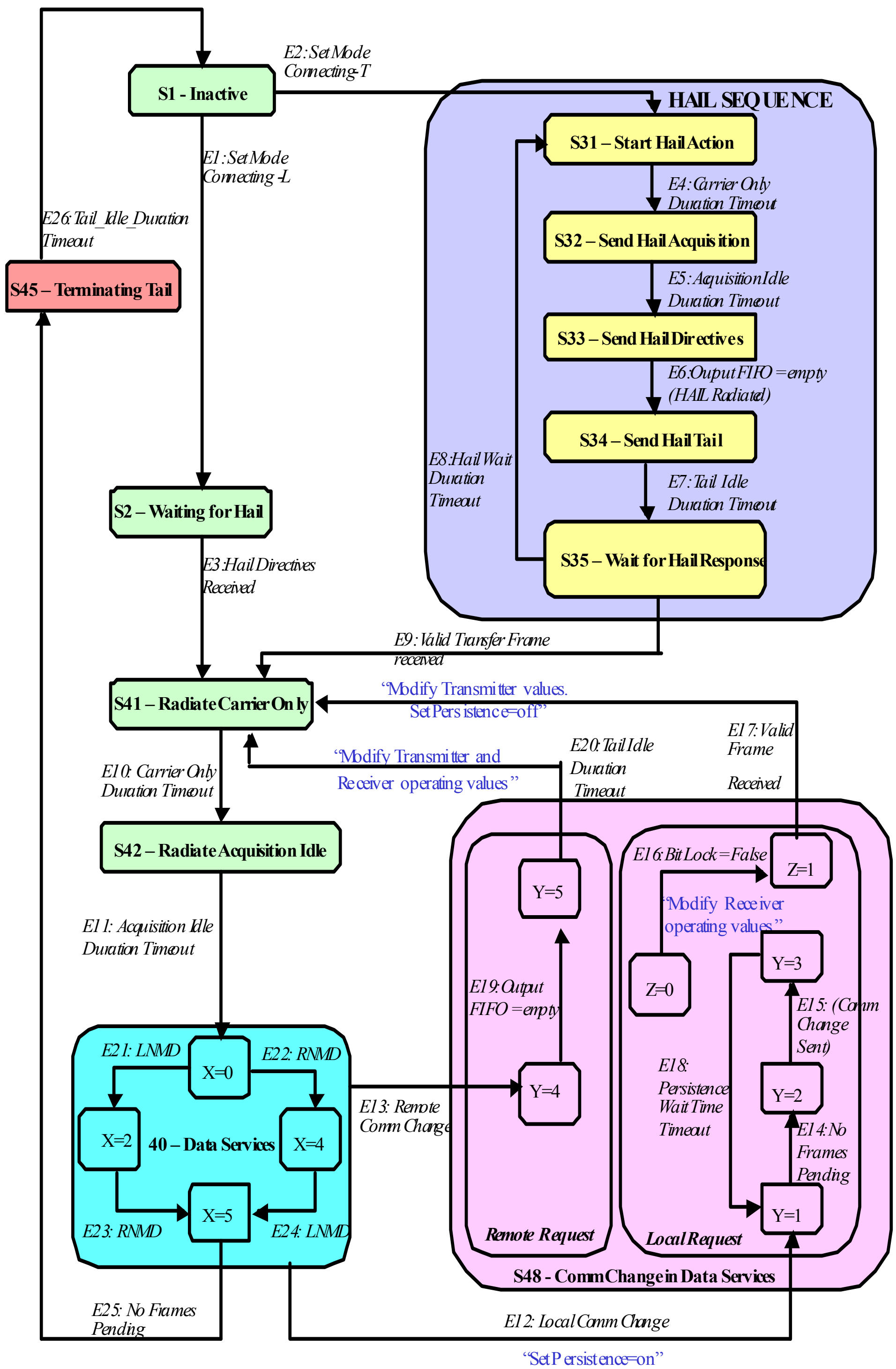


Figure 6-1: Full Duplex Transition Diagram

Table 6-8: Full Duplex Session Establishment/Data Services State Transition Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 6-2, 6-3 and *Comments*
E1	Local Directive - Set Mode Connecting-L	S1	S2	
E2	Local Directive - Set Mode Connecting-T	S1	S31	WT=Carrier_Only_Duration, Set Persistence=*on* Form and load HAIL Directives into Comm Value Buffer
E3	HAIL Directives Received (*Receive Set Transmitter/Set Receiver Parameters Directives*)	S2	S41	WT=Carrier_Only_Duration Set NEED_PLCW=*true* Set Receiver and Transmitter parameters per HAIL directives
E4	WT=1 - *Carrier_Only_Duration Timeout*	S31	S32	WT=Acquisition_Idle_Duration, Set Modulation=on
E5	WT=1 Acquisition_Idle_Duration Timeout	S32	S33	*Hail is Radiated*
E6	Output FIFO=empty	S33	S34	WT=Tail_Idle_Duration
E7	WT=1 Tail_Idle_Duration Timeout	S34	S35	WT=Hail_Wait_Duration
E8	WT=1 Hail_Wait_Duration Timeout	S35	S31	WT=Carrier_Only_Duration, Set Modulation=off
E9	Valid Transfer Frame Received - *(HAIL Response)* (or Bit_InLock_Status=true implementation option)	S35	S41	Set Transmitter values to values in Comm Value Buffer WT=Carrier_Only_Duration, Set Modulation=off, Persistence=off
E10	WT=1 *Carrier_Only_Duration Timeout*	S41	S42	WT=Acquisition_Idle_Duration, Set Modulation=on
E11	WT=1 *Acquisition_Idle_Duration Timeout*	S42	S40	*Data Service begins!*

NOTE – FOP-P Data operations (subsection 7.1) occur within State 40. FARM-P operations (subsection 7.2) occur in States 40, 41, 42 and 48 whenever MODE is active and the receiver is on. Comm Value Buffer is the local MAC buffer used for staging the transmit and receive parameters in support of the hailing and Comm Change directives. Values can be sent in locally or remotely.

Table 6-9: Full Duplex Communication Change State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 6-2, 6-3 and *Comments*
E12	Local COMM_Change Request	S40(Y=0)	S48(Y=1)	Set Y=1, Set Persistence=*on*
E13	Remote Comm_Change Request	S40(Y=0)	S48(Y=4)	Set Y=4, Set Persistence=*on*
E14	No Frames Pending	S48(Y=1)	S48(Y=2)	Form and Send Remote Comm_Change Directive (RCCD); Set Y=2
E15	Output FIFO=empty	S48(Y=2)	S48(Y=3)	WT=Persistence Wait Time, Set Y=3
E16	Bit Lock = *false*	S48(Y=1 or 2 or 3)	S48(Z=1)	Set Z=1, Set Receiver Parameters from Comm Value Buffer
E17	Valid Frame Received and Z=1	S48(Z=1)	S41	-Set Y=0, Set Persistence off, Set Z=0 -Set Transmitter Parameters and Set Receiver Parameters into Comm Value Buffer WT=Carrier_Only_Duration, Set Modulation=off
E18	WT=1 Persistence_Wait_Time Timeout	S48(Y=3)	S48(Y=1)	Set Y=1
E19	Output FIFO = empty	S48(Y=4)	S48(Y=5)	WT=Tail_Idle_Duration, Set Y=5
E20	WT=1 Tail_Idle_Duration_Timeout	S48(Y=5)	S41	-Set Y=0, Set Persistence off -Set Transmitter Parameters & Set Receiver Parameters into Comm Value Buffer -WT=Carrier_Only_Duration, Set Modulation=off

NOTE – X, Y, Z are sub-state variables used in the process of session termination and comm change.

Table 6-10: Full Duplex Session Termination State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 6-2, 6-3 and *Comments*
E21	Receive LNMD (X=0)	S40(X=0)	S40(X=2)	Form and Load RNMD directive into the MAC Queue; Set X=2; Send RNMD
E22	Receive RNMD (X=0)	S40(X=0)	S40(X=4)	Set X=4
E23	Receive RNMD (X=2)	S40(X=2)	S40(X=5)	Set X=5; *Begin Termination Process*
E24	Receive LNMD (X=4)	S40(X=4)	S40(X=5)	Form and Load RNMD directive into Mac Queue
E25	No_Frames_Pending (X=5)	S40(X=5)	S45	WT=Tail_Idle_Duration,
E26	WT=1 Tail_Idle_Duration Timeout	S45	S1	*Go inactive*
E27	Carrier_Loss_Timer Underflows	All states where Mode=active	S1	Note: Not Shown on Full Duplex Transition Diagram.
E28	Receive a Local Set Mode=Inactive Directive – or Initialize Mode Directive	Any state	S1	Note: E28 initializes operational control variables

NOTE – **LNMD** = Local No_More_Data Directive received from the local controller; **RNMD** is the Remote No_More_Data Directive over proximity link.

6.4.3 HALF DUPLEX OPERATIONS

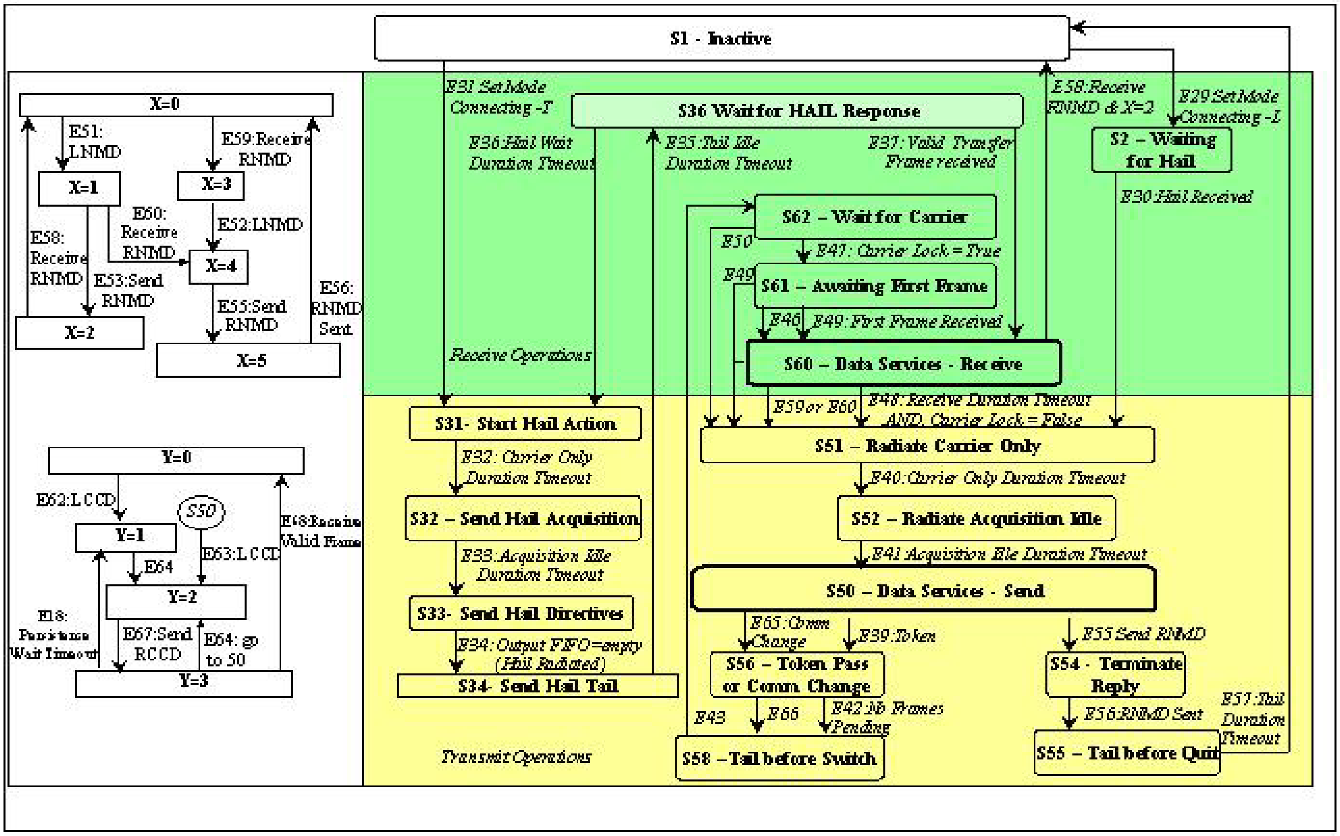


Figure 6-2: Half Duplex State Transition Diagram

Table 6-11: Half Duplex Session Establishment and Data Services

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in addition to Tables 6-1a, 6-1c and *Comments*
E29	Local Directive - Set Mode Connecting-L	S1	S2	Set NEED_PLCW=*true*
E30	HAIL Received	S2	S51	WT=Carrier_Only_Duration, Set Receiver and Transmitter values per HAIL directives
E31	Local Directive – Set Mode Connecting-T	S1	S31	WT=Carrier_Only_Duration, Load HAIL directives to Comm Value Buffer. Set Persistence = on Set Receiver Values per HAIL directive
E32	WT=1	S31	S32	WT=Acquisition Idle Duration; Set

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in addition to Tables 6-1a, 6-1c and *Comments*
	Carrier_Only_Duration Timeout			Modulation =on
E33	WT=1 Acquisition_Idle_Duration Timeout	S32	S33	*HAIL is Radiated!*
E34	Output FIFO=empty	S33	S34	WT=Tail_Idle_Duration
E35	WT=1 Tail_Idle_Duration Timeout	S34	S36	WT=Hail_Wait_Duration,; Set Modulation =off
E36	WT=1 Hail_Wait_Duration Timeout	S36	S31	-WT=Carrier_Only_Duration, Load HAIL directives to Comm Value Buffer
E37	Valid Transfer Frame Received (HAIL Response) (or bit_inlock_indicator = true implementation option)	S36	S60	-Set Transmitter values per Comm Value Buffer, Set Persistence=off WT=Receive_Duration
E38	(Transmit Timer Event – End of Send Period) WT=1 Send_Duration Timeout	S50	S50	-Set Persistence=on *Setting persistence blocks the transmission of data from data services. Now only send from the Mac Queue.*
E39	No Frames Pending .AND.X=2.AND. Y=0 .AND. Need_PLCW is false	S50 X=2 Y=0	S56	-Form and Load the Token via Set Control Parameters Directive into the MAC Queue
E40	WT=1 Carrier_Only_Duration Timeout	S51	S52	-WT=Acquisition_Idle_Duration, Set modulation=on
E41	(End of Acquire) WT=1 Acquisition_Idle_Duration Timeout	S52	S50	-WT=Send_Duration
E42	No Frames Pending (Y=0)	S56	S58	-WT=Tail_Idle_Duration

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in addition to Tables 6-1a, 6-1c and *Comments*
		Y=0		
E43	WT=1 Tail_Idle_Duration Timeout .AND. Y≠2	S58 Y≠2	S62	-WT=Receive_Duration, -Set Persistence=off, -Set Modulation =off *Switch transmit to receive*
E44	WT=1 Receive_Duration Timeout .AND. CarrierLock=true	S60	S60	-WT=Receive_Duration Notify vehicle controller – Sender exceeded prescribed transmission interval
E45	WT=1 Receive_Duration Timeout .AND. CarrierLock=true	S61	S61	-WT=Receive_Duration -Notify vehicle controller - No data transferred during contact period
E46	Receive Valid frame .AND. Y≠3	S61 Y≠3	S60	
E47	CarrierLock = true	S62	S61	
E48	WT=1 Receive_Duration Timeout .AND. CarrierLock = false	S60	S51	-WT=Carrier_Only_Duration *back-up action for missed token* *Switch receive to transmit*
E49	Receive Token - Set Control Parameters Directive	60/S61	S51	-WT=Carrier_Only_Duration *Switch receive to transmit*
E50	WT=1 Receive_Duration Timeout .AND. CarrierLock = false	S62	S51	-WT=Carrier_Only_Duration -Notify vehicle controller -No carrier received for contact period *Switch receive to transmit*
NOTE – FOP-P Data operations occur within State 50 and are described in 7.1. FARM-P operations occur within States 60 and 61 are described in 7.2.1.				

Table 6-12: Half Duplex Communication Change State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Additional Action(s) and *Comments*
E62	Receive Local Comm Change Directive (LCCD)	Any State other than State 50	No State Change Y=1	Load Set Transmitter/Set Receiver Parameters Directives values into Comm Value Buffer
E63	Receive Local Comm Change Directive (LCCD)	50	50 Y=2	-Set Persistence=on -Set Receiver Parameters from Comm Value Buffer
E64	Transition to State 50	Y=1 .OR. Y=3	50 Y=2	-Set Y=2, Set Persistence=on -Set Receiver Parameters from Comm Value Buffer
E65	No Frames Pending .AND. Y=2	50 Y=2	56	-Form and load into the Comm Value Buffer the Comm_Change Directives
E66	No Frames Pending	56 Y=2	58 Y=2	-WT=Tail_Idle_Duration *Comm Change Sent*
E67	WT=1Tail_Idle_DurationTimeout .AND. Y=2	58 Y=2	62 Y=3	-WT=Receive_Duration, *Switch transmit to receive*
E47	CarrierLock = true	62	61	*Same event - provided for clarity*
E68	Receive Valid Frame	61 Y=3	60 Y=0	-Set Transmitter Parameters from Comm Value Buffer Set Y=0, Persistence=off
E69	Receive Comm_Change (*Not Shown in State Transition Diagram)*	60/61	51	-Set Transmitter & Receiver Parameters into Comm Value Buffer -Set NEED PLCW=true

Table 6-13: Half Duplex Session Termination State Table

Event No	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Additional Action(s) and *Comments*
E51	Receive LNMD (can be received at any time)	X=0	X=1	Set X=1
E52	Receive LNMD (can be received at any time)	X=3	X=4	Set X=4
E53	No Frames Pending .AND. X=1	S50	S50	Form and Load RNMD into

Event No	**Event Causing the Transition (Description)**	**Starting State (from)**	**Resulting State (to)**	**Additional Action(s) and *Comments***
		X=1	X=2	the MAC Queue, Set X=2; *Send RNMD*
E55	No Frames Pending .AND. X=4	S50 X=4	S54 X=5	Form and Load RNMD into the MAC Queue, Set X=5; *Send RNMD*
E56	No Frames Pending .AND. X=5	S54 X=5	S55 X=0	WT=Tail_Idle_Duration Set X=0 *Transmission of RNMD complete*
E57	WT=1 Tail_Duration Timeout	S55	S1	*Go inactive*
E58	Receive RNMD .AND. X=2	S60/S61 X=2	S1 X=0	Terminate; Set X=0 *Both nodes have no more data to send*
E59	Receive RNMD .AND. X=0	S60/S61 X=0	S51 X=3	SET X=3 (WT = Carrier_Duration_Only)
E60	Receive RNMD .AND. X=1	S60/S61 X=1	S51 X=4	SET X=4 (WT = Carrier_Duration_Only)
E61	Receive either a Local or Remote Mode=Inactive Directive -or Mode=Initialize Directive	any	S1	E8 initializes Data Service variables *Not shown on Half Duplex State Transition Diagram*
E70	Carrier_Loss_Timer Underflows	S60/S61/ S62	S1	*Not Shown on Half Duplex Transition Diagram.*

6.5 SIMPLEX OPERATIONS

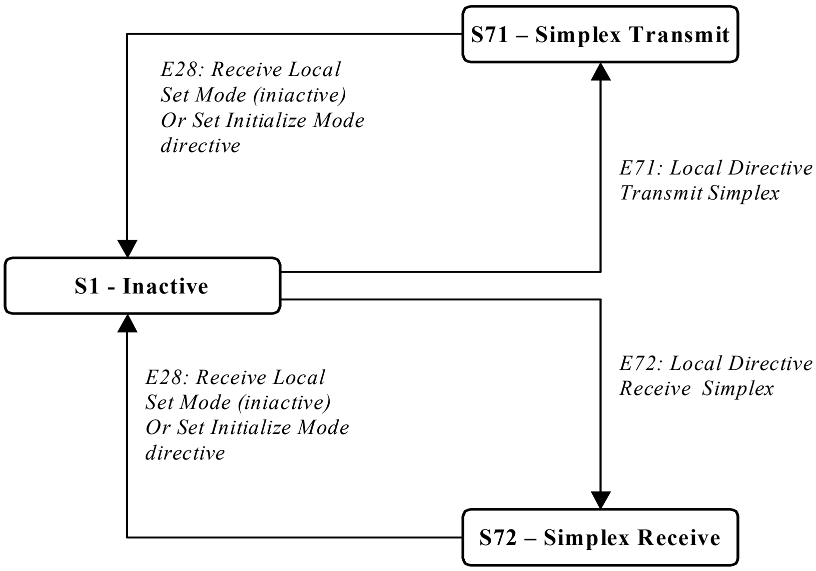


Figure 6-3: Simplex Operations

Table 6-14: Simplex State Transition Table

Event No	Starting State (from)	Resulting State (to)	Event Causing the Transition (Description)	Action(s) in addition to Tables 6-2, 6-5
E71	1	S71	Local Directive -Transmit Simplex	Set Duplex = Simplex, Set Transmit =on, Set MODE=active
E72	1	S72	Local Directive -Receive Simplex	Set Duplex = Simplex, Set Transmit=off, Set MODE=active
E28	S71 or S72	S1	Receive a Local Set Mode=Inactive Directive – or Initialize Mode Directive	Set MODE=inactive

6.6 INTERFACES WITH THE PHYSICAL LAYER

6.6.1 OUTPUT INTERFACES

6.6.1.1 When ‘on’, the Transmit Variable requires the transceiver to have its transmitter ‘on’.

6.6.1.2 The Output Bitstream Port shall supply the series of bits to be radiated.

6.6.1.3 When true, the Modulation Signal requires the transceiver to modulate the carrier with the data provided on the Output Bitstream.

6.6.2 INPUT INTERFACES

a) Output Bit Clock. The Output Bit Clock is provided by the transceiver and shall control the rate at which data is shifted from the Output Bitstream FIFO, via the Output Bitstream Port, to the transceiver’s modulator for radiation.

b) Received Bitstream Data.

c) Received Bit Clock.

d) Carrier_Acquired Signal. Carrier_Acquired Signal shall signal that the receiver has acquired a carrier signal. The **Carrier_Acquired** signal shall be set to *true* when the receiver is locked to the received RF signal, and *false* when not in lock.

e) Bit_InLock_Indicator. Bit_InLock_Indicator shall be used to signal that bit synchronization has been acquired, and that the received serial bit stream is being provided to the C&S sublayer by the Physical layer. The **Bit_In_Lock_Status** signal shall be set to *true* when the receiver is confident that its bit detection processes are synchronized to the modulated bit stream, and that the bits output are of an acceptable quality for processing by the Data Link layer. It shall be set to *false* when the receiver is not in bit lock.

6.7 SENDING OPERATIONS

6.7.1 OVERVIEW

A Local SET Transmitter Parameters and Local Set Receiver Parameters directive will set the local transceiver to the desired physical configuration. As required for the session, the loading of the TEST_SOURCE variable is also completed.

The Local SET MODE (*Connecting-T*) directive initiates the HAIL activity and starts the session establishment process (see 6.4.2 for full duplex operation and 6.4.3 for half duplex operation).

Once a frame is ready for output, an ASM is pre-pended, and a CRC is computed and appended to the frame. The output bitstream is formulated for radiation in accordance with table 6-15.

NOTE – An idle pattern generated by a Fill generator (described in 4.1.5.2) is used for acquisition periods, i.e., periods when no frames are available for transmission, as well as for providing a tail stream (which provides the added bits required to push the data through the receiving and decoding processes at the remote terminus of the link).

6.7.2 OUTPUT BITSTREAM FORMULATION

Table 6-15: Data Source Selection for Output Bit Stream with Transmit = *on* and Modulation = *on*

States	**Based Upon the Values Below, Take the Following Action**				**Action**
SS (Sub-State)	SPDU Pending	P (Persistence)	NEED_ PLCW	SDU Pending	Data to be loaded into output FIFO when Output FIFO is empty
2,4,7	X	X	X	X	IDLE (Acquisition or Tail)
0,3,6	***true***	X	X	X	ASM+P-Frame(SPDU)+CRC
0,3,6	*false*	***true***	X	X	IDLE
0,3,6	*false*	*false*	***true***	X	ASM+PLCW+CRC
0,3,6	*false*	*false*	*false*	***true***	ASM+U-Frame(SDU) +CRC
0,3,6	*false*	*false*	*false*	*false*	IDLE

NOTES

1 X means don't care what the value is.

2 SPDU Pending is true if there is a supervisory protocol data unit available to send.

3 SDU Pending is true if there is a service data unit (user data) available to send.

4 NEED_PLCW is true when a PLCW or Status report is required.

5 PERSISTENCE is a variable used for selected Supervisory protocol activities.

6 The selection of an SDU issues an extract data unit request to the FOP-P. (See FOP-P data selection, described in 7.1)

6.7.3 PROVISION OF U-FRAME FOR SELECTION

NOTE – The provision of a U-FRAME for selection through use of the procedures contained in table 6-15 is defined in the FOP-P portion of the COP-P specification (see 7.1). A single Physical Channel (PC) is described in this specification. The use of multiple PCs is possible but concurrent COP-P procedures are required and the reporting is then required to contain the status for each PC. Data prioritization and its multiplexing for selection into the output bitstream as specified above is outside the scope of this document.

6.7.4 EVENTS RELATED TO DATA HANDLING ACTIVITIES

6.7.4.1 Reset NEED_PLCW (i.e., set to *false*) shall be generated whenever a PLCW is chosen for output.

6.7.4.2 No_Frames_Pending shall be *true* when none of the conditions for selecting an SPDU (including a PLCW) or U-FRAME are satisfied.

6.7.4.3 Output FIFO = empty shall be *true* when the last bit contained within the Output is extracted.

6.8 RECEIVING OPERATIONS

6.8.1 The SET MODE (*Connecting-L*) or SET MODE (*Connecting-T*) local directives shall establish the physical channel characteristics and initializes the receiving procedures.

6.8.2 When the Receive State is *on,* the received bitstream shall be processed to delimit the contained frames (this process requires frame synchronization and frame length determination using the frame header length field).

6.8.3 Frame Validation Criteria are as follows:

a) The delimited frame and the attached CRC-32 shall be processed to determine if the frame contains errors. Erred frames shall be rejected as invalid.

b) The Frame Version Number shall equal binary '10', otherwise the frame shall be rejected as invalid.

c) The Spacecraft ID (SCID) field in the transfer frame header shall contain the value of the Local_Spacecraft_ID (MIB parameter) when the Source/Destination Identifier value equals ('0') *destination,* otherwise the frame shall be rejected as invalid.

d) The SCID field shall contain the value equal to the RECEIVING_SCID_BUFFER for all frames (i.e., Remote_Spacecraft_ID, MIB parameter) when the TEST_SOURCE is *true.* When the SCID field and RECEIVING_SCID_BUFFER disagree, then a session violation has occurred and the vehicle controller shall be notified.

e) If the PCID field is used to address a physical transceiver, then the PCID in the received transfer frame header shall contain the value equal to the Receiving_PCID MIB parameter. When the PCID and the Receiving_PCID disagree, then a session violation has occurred and the vehicle controller shall be notified.

NOTE – The Expedited frame counter will increment for each validated expedited frame received.

6.8.4 Validated received User Data frames (U-frames) shall be processed per the COP-P process described in 4.4.3.

6.8.5 Validated Supervisory Protocol frames (P-frames) shall be processed by first delimiting the contained SPDUs. One or more PLCWs contained within SPDUs shall be transferred to the COP-P processor while all other reports or directives are processed for protocol actions.

7 DATA SERVICES OPERATIONS (COP-P)

7.1 SENDING PROCEDURES (FOP-P)

7.1.1 QUEUE

The FOP-P shall maintain a single output queue. The *Sent Frame queue* contains Sequence Controlled frames that have been sent but not yet acknowledged by the Receiver. (This name is abbreviated to *Sent Queue* in the state table).

NOTE – The local directive, Clear Queue (Queue Type) allows for the clearing of frames within the Sent Queue.

7.1.2 INTERNAL COP-P VARIABLES

a) **VE(S)**: an 8-bit positive integer. Its value shall represent the sequence number plus one (modulo 256) of the next Expedited Frame to be sent.

b) **V(S)**: an 8-bit positive integer. Its value shall represent the sequence number plus one (modulo 256) of the next new Sequence Controlled Frame to be sent.

c) **VV(S)**: an 8-bit positive integer. Its value shall represent the sequence number (modulo 256) to be assigned to the next Sequence Controlled Frame to be sent. It equals V(S) unless a retransmission is in-progress.

d) **N(R)**: an 8-bit positive integer. It is a copy of the Report Value (see 3.2.8) from the current PLCW. It shall represent the sequence number plus one (modulo 256) of the last Sequence Controlled frame acknowledged by the Receiver.

e) **NN(R)**: an 8-bit positive integer. It is a copy of the Report Value from the previous valid PLCW. It is a modulo 256 counter.

f) **R(R)**: a Boolean variable (i.e., its value is either *true* or *false*). It is a copy of the Retransmit Flag from the current PLCW. It shall indicate whether or not Sequence Controlled frame(s) need to be retransmitted.

g) **RR(R)**: a Boolean variable. It is a copy of the Retransmit Flag from the previous valid PLCW.

h) **NEED_PLCW**: a Boolean parameter. It shall indicate whether or not a new PLCW needs to be sent (the PLCW needs to be sent whenever its contents change).

i) **SYNCH_TIMER**: the time a Sender will wait to receive a valid PLCW from a Receiver before taking action to synchronize with the Receiver. The initial or reinitialization value associated with this timer (Synch_Timeout) is expressed in milliseconds.

7.1.3 FOP-P STATE TABLE EVENTS

7.1.3.1 General

'Remove acknowledged frames from Sent Queue'

Remove *n* frames from the Sent Queue, where *n* = N(R) - NN(R) (i.e., the number of times that NN(R) has to be incremented to reach N(R))

Clear SYNCH_TIMER;

'Start SYNCH_TIMER'

Set the SYNCH_TIMER value to the value of the MIB parameter, Synch_Timeout when the value of the SYNCH_TIMER is equal to 0.

The SYNCH_TIMER counts down when it's value is non-zero. When the SYNCH_TIMER counts down to 0, the SYNCH_TIMER expires and the Resync Event is triggered.

Note: If the value of Synch_Timeout is 0, then the SYNCH_TIMER never expires.

'Clear SYNCH_TIMER'

Set the SYNCH_TIMER value to 0. This does not trigger a Resync Event.

'Store this PLCW'

Assign the value of N(R) to NN(R);

Assign the value of R(R) to RR(R);

7.1.3.2 'Resync Event'

When the SYNCH_TIMER expires, this triggers the resync event:

a) Notify the vehicle controller that the SYNCH_TIMER expired.

b) If resync_local = true, then initiate the SET V(R) activity, or else notify the local vehicle controller about the COP-P loss of synchronization.

7.1.3.3 SET V(R) Activity

SET V(R) Activity is as follows:

a) MAC Sublayer builds a SET V(R) directive, copying NN(R) into the V(R) field within the SET V(R) directive;

b) the MAC Sublayer loads this directive into the MAC Queue for transmission and sets MAC_frame_pending = *true*;

c) the MAC Sublayer sets PERSISTENCE = *true*. Upon receipt of a PLCW with N(R) = NN(R), PERSISTENCE is set to *false.*

7.1.3.4 FOP-P State Table

Events	Event #/Name	Action	Comment

Initialization			
'Entered this state' when turned 'on'	**SE0** **Initialization**	V(S) = VE(S) = VV(S) = NN(R)=N(R)= 0; R(R) = RR(R) = *false*; NEED_PLCW = *true*;	

PLCW received			
PLCW Content: **R(R) RR(R) N(R) Relationship**	**Event #/Name**	**Action**	**Comment**
X X N(R) < NN(R); or X X N(R) > V(S); or PLCW does not match PLCW Format; or '0' '1' NN(R) = N(R) = V(S); or '1' 'X' " " or '0' '1' NN(R) = N(R) < V(S); or '1' 'X' NN(R) < N(R) = V(S)	**SE1** Invalid PLCW	VV(S) = NN(R); Start SYNCH_TIMER Procedure;	"Invalid N(R)" "Invalid N(R)" no comment "Retransmit cleared but no frames acknowledged" "Retransmit set but no frames pending" "Retransmit cleared but no frames acknowledged" "Retransmit set but all frames acknowledged"
'0' '0' NN(R) = N(R) = V(S); or '0' '0' NN(R) = N(R) < V(S); or '1' '1' NN(R) = N(R) < V(S);	**SE2** No Operation	Ignore	"There are no pending frames" "No pending frames are acknowledged" "Retransmit; No pending frames acknowledged"
'X' 'X' NN(R) ≤ VV(S) < N(R) < V(S) or '1' 'X' NN(R) < N(R) < VV(S) < V(S)	**SE3a** Acknowledgments In Process	Remove acknowledged frames from Sent Queue Procedure; VV(S) = N(R); 'Store this PLCW' Procedure;	"Some pending frames are acknowledged"
'0' 'X' NN(R) < N(R) < VV(S) < V(S)	**SE3b** Acknowledgments In Process	Remove acknowledged frames from Sent Queue Procedure; 'Store this PLCW' Procedure;	"Some pending frames are acknowledged"

Events	Event #/Name	Action	Comment
‘0’ ‘X’ NN(R) < N(R) = V(S)	**SE4** Acknowledgments Complete	Remove acknowledged Frames from Sent Queue Procedure; VV(S) = N(R); ‘Store this PLCW’ Procedure;	“All pending frames are acknowledged”
‘1’ ‘0’ NN(R) = N(R) < V(S)	**SE5** No Acknowledgments	VV(S) = N(R); ‘Store this PLCW’ Procedure;	“Retransmit; no pending frames acknowledged”

SYNCH_TIMER expired	**SE6**	Initiate Resynchronization Procedure	
Interface to Frame sublayer			This event is used to output frames from COP-P

Events	Event #/Name	Action	Comment

When Extract_Frame_Request transitions from *false to true.*
‘Frame Sublayer is ready for another frame’
NOTE: This is signal is generated when DS Frame Pending is True (Exp avail=true .OR. NN(R)<V(S) .OR. SEQ Avail=true)
	SE7
	Frame Sublayer needs frame to transmit
		IF (EXPEDITED_FRAME_AVAILABLE = *true*)
		Remove frame from EXP Queue;
		Assign VE(S) to the frame;
		Increment VE(S);
		Report VE(S) to the I/O Sublayer;
		Transfer it to the Frame Sublayer;
		ELSE
		IF ((V(S) – NN(R) = Transmission_Window)[5] .AND. (VV(S) = V(S)))
		VV(S) = NN(R);
		END IF
		IF (VV(S) < V(S))
		Copy frame number VV(S) from the Sent Queue;
		Increment VV(S);
		Transfer this frame to the Frame Sublayer;
		Start SYNCH_TIMER Procedure;
		ELSE
		IF (SEQUENCE_CONTROLLED_FRAME_AVAILABLE = *true*)
		Remove frame from SEQ Queue;
		Assign V(S) to the frame;
		Insert a copy of the frame to the end of the Sent Queue;
		Increment V(S);
		Report V(S) to the I/O Sublayer;
		Transfer this frame to the Frame Sublayer;
		ELSE
		IF (PERSISTENCE = *false)*
		Notify Spacecraft Controller of ‘End_of_Data’ Condition;
		END IF
		END IF
		END IF
		END IF	

Events	Event #/Name	Action	Comment
Directives			
Set Transmission_Window	**S8**	Accept; Set;	
Set Synch_Timeout	**SE9**	Accept; Set;	
Invalid directive	**SE10**	Reject;	

NOTES

1 ‘X’ means ‘not applicable’; ‘0’ means *false;* ‘1’ means *true.*

2 At program startup, initialize the program variables:
R(R) = *false*; RR(R) = *false*; N(R) = 0; NN(R) = 0; V(S) = 0; VV(S) = 0;
Trigger event SE0 before allowing any other events to occur.

3 Event SE0 is to be triggered implicitly whenever the COP-P Sender is turned on (either upon initialization or after the Resynchronization process).

4 V(S), NN(R), N(R) and VV(S) are single octet variables that are modulo 256 counters. Thus when differencing any combination of these variables, the use of modulo 256 arithmetic is required. Thus when differencing two of these variables one must determine if the first variable is greater than the second. If not, then one must add 256 to the initial variable. Thus the difference between V(S) and NN(R), for example, needs to be computed in the following manner in order to arrive at the correct value: If V(S)>NN(R) .OR. V(S) = NN(R) then DELTA_VALUE = V(S)- NN(R); If V(S)<NN(R) then DELTA_VALUE = 256+V(S)-NN(R).

5 Transmission_Window (MIB parameter): The maximum number of Sequence Controlled frames that can be unacknowledged at any given time. For example, if the Transmission_Window is 10 and the Sender sends 10 Sequence Controlled frames, the Sender must wait for at least one of those frames to be acknowledged by the Receiver before it can send any additional Sequence Controlled frames. The value of Transmission_Window cannot exceed 127.

7.2 DATA SERVICES RECEIVING OPERATIONS

7.2.1 FARM-P STATE TABLE

Events	Event #/Name	Action	Comment
'Entered this state' when turned 'on' except for State DS-8 (Simplex, FARM-P = *off*)	**RE0** **Initialization**	R(S) = *false*; V(R) = *0*; EXPEDITED_FRAME_COUNTER = *0*; NEED_PLCW = *true*;	
Invalid frame arrives	**RE1** **Invalid Frame**	Discard the frame;	
Valid 'SET V(R)' frame arrives	**RE2** **SET V(R)**	R(S) = *false*; Set V(R) to the value specified by the frame; NEED_PLCW = *true*;	
Valid Expedited frame arrives	**RE3** **Valid Expedited Frame**	Accept/Pass the frame to I/O sublayer; Increment EXPEDITED_FRAME_COUNTER;	
Valid Sequence Controlled frame arrives, N(S) = V(R)	**RE4** **Sequence Frame 'in-sequence'**	Accept/Pass the frame to I/O sublayer; R(S) = *false*; Increment V(R); NEED_PLCW = *true*;	
Valid Sequence Controlled frame arrives, N(S)>V(R)	**RE5** **Sequence Frame 'out-of-sequence'**	Discard the frame; R(S) = *true*; NEED_PLCW = *true*;	
Frame sublayer requests content for PLCW	**RE6** **Report PLCW contents**	Report value of R(S), V(R), and EXPEDITED_FRAME_COUNTER;	
Valid Sequence Controlled frame arrives, N(S)<V(R)	**RE7** **Frame already received**	Discard the frame;	

7.2.2 INTERNAL PARAMETERS

a) **V(R)**: an 8-bit positive integer. Its value shall represent the sequence number plus one (modulo 256) of the last Sequence Controlled Frame acknowledged by the Receiver.

b) **R(S)**: a Boolean variable (i.e., its value is either *true* or *false*) that is copied to the PLCW and shall indicate whether or not Sequence Controlled frame(s) need to be retransmitted.

c) **EXPEDITED_FRAME_COUNTER**: a three-bit positive integer. Its value represents the number of Expedited frames received (modulo 8). This counter may be used by the receiver to keep track of the number of expedited frames received over a communications session.

7.2.3 INTERFACE TO THE I/O LAYER

FARM-P shall pass valid expedited and valid in-sequence U-frames to the I/O sublayer where they shall be buffered, assembled into packets as required, and then delivered via the specified output port.

8 INPUT/OUTPUT (I/O) SUBLAYER OPERATIONS

NOTE – The I/O sublayer provides the interface with the spacecraft data provider and data recipient. This section describes operations with a single user data source and single proximity channel. Note that implementations are not limited to a single data source. The fundamental role of the I/O sublayer is to form the frame data units for transfer across the link, and to pass received data units out to the physical and logical destinations identified in the received frame.

8.1 SENDING OPERATIONS

The Sending Side of the I/O sublayer shall interface with the data supplier. This sublayer shall provide the procedures that accept the user service data units and prepares them for transfer across the communications channel. The I/O sublayer may be required to parse large input packets into segments compatible with the Max_Size_PLTU_Received MIB parameter for asynchronous data link channel operations. The I/O sublayer shall assemble the data units for inclusion into frames in accordance with the restrictions imposed by various MIB parameters. The I/O sublayer shall receive the user service data unit along with its routing and control instructions. These instructions are required for the formulation of the frame header and to determine whether data units can be combined into the same frame or not. The frame construction rules state that all data units within the same frame must be addressed to the same spacecraft destination, contain the same PDU type ID, the same physical channel ID, the same output Port ID, have the same QOS and must be of the same service data unit type (DFC_ID). The I/O sublayer shall have the responsibility to inform the data supplier which service data units were transmitted and, in the case of Sequence Controlled service, which data units were acknowledged as received by the communications partner. This notification is essential to enable reliable data service operations across multiple sessions, if desired.

8.2 RECEIVING OPERATIONS

NOTE – The Receiving Side of the I/O sublayer interfaces shall has a multitude of possible interfaces with the spacecraft. One of eight possible output ports can be identified in the frame using the Port ID field.

The role of this sublayer shall be to route a received ‘complete’ data unit to the identified port. When segmentation is used, the I/O sublayer shall accept received segments and try to re-assemble the user’s data unit. Delivery shall only provided for completely re-assembled data units i.e., partial data units shall not be delivered to the end user.

ANNEX A
VARIABLE-LENGTH SUPERVISORY PROTOCOL DATA FIELD FORMATS

(This annex **is** part of the Recommendation.)

NOTE – See table 3-4 for a complete overview of the variable-length SPDU structure including the SPDU header and SPDU data field.

A1 SPDU TYPE 1: DIRECTIVE/REPORT/PLCW SPDY DATA FIELD

A1.1 OVERVIEW

The Directive/Report/PLCW SPDU shall be used for space link supervisory configuration and control of the transceiver and its operation.

The SPDU data field shall be a container that can hold up to seven (16 bit) discrete self-delimiting and self-identifying directives:

a) each directive shall have a specific functionality;

b) each directive shall be 16 bits in length and shall be self identified by the value in the Directive Type field (contained in bits 13, 14, and 15 of the directive);

c) the directives shall be concatenated without intervening bits within the data field.

NOTE – See figure A-1 for TYPE 1 SPDU Data Field Contents.

<table>
<tr><td colspan="9"></td><td>Directive Type ID 3 bits (13,14,15)</td></tr>
<tr><td>Mode (0,1,2)</td><td>Data Rate (3,4,5,6)</td><td colspan="3">Modulation (7)</td><td colspan="2">Data encoding (8,9)</td><td colspan="2">Frequency (10,11,12)</td><td>‘000’ =SET TRANSMITTER PARAMETERS</td></tr>
<tr><td colspan="3">Time Sample (0,1,2,3,4,5,6,7,8,910)</td><td colspan="4">Remote No More Data (11)</td><td colspan="2">Token (12)</td><td>‘001’ = SET CONTROL PARAMETERS</td></tr>
<tr><td>Mode (0,1,2)</td><td>Data Rate (3,4,5,6)</td><td colspan="3">Modulation (7)</td><td colspan="2">Data encoding (8,9)</td><td colspan="2">Frequency (10,11,12)</td><td>‘010’ = SET RECEIVER PARAMETERS</td></tr>
<tr><td colspan="5">Receiver Frame Sequence Number (SEQ_CTRL_FSN)(0,1,2,3,4,5,6,7)</td><td colspan="3">Reserved (8,9,10,11)</td><td>PCID (12)</td><td>‘011’ = Set V(R)</td></tr>
<tr><td>Reserved (0,1,2)</td><td>Status Report Request (3,4,5,6,7)</td><td colspan="3">Time-Tag Request (8,9,10)</td><td colspan="2">PCID 0 PLCW Request (11)</td><td colspan="2">PCID 1 PLCW Request (12)</td><td>‘100’ = Report Request</td></tr>
<tr><td colspan="2">Report Value (0,1,2,3,4,5,6,7)</td><td colspan="4">Expedited Frame counter (8,9,10)</td><td>PCID (11)</td><td colspan="2">Retransmit (12)</td><td>‘101’ = PLCW</td></tr>
<tr><td colspan="4">Reserved (0,1,2,3,,4,5,6,7,8,9,10)</td><td colspan="5">Report Type (11,12)</td><td>‘110’=Status Report</td></tr>
<tr><td colspan="4">Source Spacecraft ID (0,1,2,3,4,5,6,7,8,9)</td><td colspan="5">Reserved (10,11,12)</td><td>‘111’ = Report Source S/C I/D</td></tr>
</table>

Figure A-1: TYPE 1 SPDU Data Field Contents

A1.2 SET TRANSMITTER PARAMETERS DIRECTIVE

A1.2.1 Overview

The SET TRANSMITTER PARAMETERS directive shall consist of six fields, positioned contiguously, in the following sequence:

a) Directive Type (three bits);

b) Transmission Frequency (three bits);

c) Transmission Data Encoding (two bits);

d) Transmission Modulation (one bit);

e) Transmission Data Rate (four bits);

f) Transmission (TX) Mode (three bits).

NOTE – The structural components of the SET TRANSMITTER PARAMETERS directive are shown in figure A-2.

Bit 0 Bit 15

TX Mode 3 bits	TX Data Rate 4 bits	TX Modulation 1 bit	TX Data encoding 2 bits	TX Frequency 3 bits	Directive Type 3 bits
0,1,2	3,4,5,6	7	8,9	10,11,12	13,14,15

Figure A-2: SET TRANSMITTER PARAMETERS Directive

A1.2.2 Directive Type

A1.2.2.1 Bits 13–15 of the SET TRANSMITTER PARAMETERS directive shall contain the Directive Type.

A1.2.2.2 The 3-bit Directive Type field shall identify the type of protocol control directive and shall contain the binary value ‘000’ for the SET TRANSMITTER PARAMETERS directive.

A1.2.3 Transmission Frequency

A1.2.3.1 General

Bits 10–12 of the SET TRANSMITTER PARAMETERS directive shall be used to set the transmitter frequency to the desired value.

A1.2.3.2 Forward Link

In the context of the forward link, this three-bit field shall define the transmit frequency channel component. Actual frequency assignments are given in the physical layer (see annex F).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch1R	Ch 2R	Ch3R	Ch4R	Ch5R	Ch6R	Ch7R	Ch8R

A1.2.3.3 Return Link

In the context of the return link, this three-bit field shall define the return frequency channel component. Actual frequency assignments are given in the physical layer, (see annex F).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch1F	Ch2F	Ch3F	Ch4F	Ch5F	Ch 6F	Ch7F	Ch8F

A1.2.3.4 Transmission Data Encoding

Bits 8–9 of the SET TRANSMITTER PARAMETERS directive shall contain the following coding options:

a) ‘00’ = Reserved;

b) ‘01’ = Convolutional Code(7,1/2) (G2 vector inverted) with attached CRC-32;

c) ‘10’ = Uncoded with attached CRC-32;

d) ‘11’ = Reserved.

A1.2.3.5 Transmission Modulation

Bit 7 of the SET TRANSMITTER PARAMETERS directive shall contain the transmission modulation options:

a) ‘1’ = Non-coherent PSK;

b) ‘0’ = Coherent PSK.

A1.2.3.6 Transmission Data Rate

A1.2.3.6.1 Bits 3–6 of the SET TRANSMITTER PARAMETERS directive shall contain one of the following transmission data rates (rates in kbps, i.e., powers of 10).

NOTE – Because of the NASA 2001 Mars Odyssey implementation, there is an added constraint on the use of the values in the Data Rate field for 8, 32, 128, 256 Kbps. Data rate selection is linked to the modulation field value as shown in the tables below. NC indicates non-coherent PSK, and C indicates coherent PSK. R1 through R4 indicates the field is reserved for future definition by the CCSDS.

A1.2.3.6.2 Ordered by Data Rate:

‘1000’	‘1001’	‘0000’	‘0001’	‘1100’	‘0010’	‘0011’	‘1101’	‘0100’	‘0101’	‘0110’	‘0111’	‘1010’	‘1011’	‘1110’	‘1111’
2	4	8 NC	8 C	16	32 NC	32 C	64	128 NC	128 C	256 NC	256 C	R1	R2	R3	R4

A1.2.3.6.3 Ordered by Bit pattern:

‘0000’	‘0001’	‘0010’	‘0011’	‘0100’	‘0101’	‘0110’	‘0111’	‘1000’	‘1001’	‘1010’	‘1011’	‘1100’	‘1101’	‘1110’	‘1111’
8 NC	8 C	32 NC	32 C	128 NC	128 C	256 NC	256 C	2	4	R1	R2	16	64	R3	R4

A1.2.3.7 Transmission Mode

A1.2.3.7.1 Bits 0–2 of the SET TRANSMITTER PARAMETERS directive shall contain the Transmission Mode options.

A1.2.3.7.2 Bit pattern assignments shall be defined in the MIB.

A1.3 SET CONTROL PARAMETERS

A1.3.1 Overview

The SET CONTROL PARAMETERS directive shall consist of four fields, positioned contiguously, in the following sequence:

a) Directive Type (3 bits).

b) Token (1 bit);

c) Remote No More Data (1 bit);

d) Reserved (5 bits);

e) Time Sample (6 bits).

This directive is used to set one of three independent conditions at a time: 1) setting the token for half duplex operations; 2) setting the remote no more data condition for session termination in full or half duplex; 3) setting the number of time samples to be taken during Timing Services.

NOTE – The structural components of the SET CONTROL PARAMETERS directive are shown in figure A-3.

Bit 0 Bit 15

Time Sample 6 bits	Reserved 5 bits	Remote No More Data 1 bit	Token 1 bit	Directive Type 3 bits
0,1,2,3,4,5	6,7,8,9,10	11	12	13,14,15

Figure A-3: SET CONTROL PARAMETERS Directive

A1.3.2 Directive Type

A1.3.2.1 Bits 13–15 of the SET CONTROL PARAMETERS directive shall contain the Directive Type.

A1.3.2.2 The three-bit Directive Type field shall identify the type of protocol control directive and shall contain the binary value '001' to identify the SET CONTROL PARAMETERS directive.

A1.3.3 Token

Bit 12 of the SET CONTROL PARAMETERS directive shall contain the value of the Token field. Either this field notifies the remote node that there is no change in who has permission to transmit (i.e., ignore this field), or it commands the remote node to the transmit state, as follows:

a) '0' = No Change;

b) '1' = Transmit.

A1.3.4 Remote No More Data

Bit 11 of the SET CONTROL PARAMETERS directive shall contain the Remote No More Data field. . Either this field notifies the recipient node that there is no change in the remote node's data state (i.e., ignore this field), or it notifies the recipient node that the remote node has no more data to send, in which case the session may be terminated when the recipient node locally has no more data to send, as follows:

a) '0' = No Change;

b) '1' = No More Data to Send (RNMD).

A1.3.5 Reserved

Bits 6-10 of the SET CONTROL PARAMETERS directive shall contain spares.

A1.3.6 Time Sample

Bits 0-5 of the SET CONTROL PARAMETERS directive shall contain the Time Sample field. When this field is non-zero, it notifies the recipient to capture the time and frame sequence number (associated with the Proximity Timing Service i.e., Section 5) for the next n frames received. Where n is the number of proximity transfer frames contained within the Time Sample Field.

A1.4 SET RECEIVER PARAMETERS DIRECTIVE

A1.4.1 Overview

The SET RECEIVER PARAMETERS directive shall consist of six fields, positioned contiguously, in the following sequence:

a) Directive Type (three bits);

b) Receiver Frequency (three bits);

c) Receiver Data Decoding (two bits);

d) Receiver Modulation (one bit);

e) Receiver Data Rate (four bits);

f) Receiver (RX) Mode (three bits).

NOTE – The structural components of the SET RECEIVER PARAMETERS directive are shown in figure A-4.

Bit 0 | Bit 15

RX Mode 3 bits	RX Rate 4 bits	RX Modulation 1 bit	RX Data Decoding 2 bits	RX Frequency 3 bits	Directive Type 3 bits
0,1,2	3,4,5,6	7	8,9	10,11,12	13,14,15

Figure A-4: SET RECEIVER PARAMETERS Directive

A1.4.2 Directive Type

A1.4.2.1 Bits 13–15 of the SET RECEIVER PARAMETERS directive shall contain the Directive Type.

A1.4.2.2 The three-bit Directive Type field shall identify the type of protocol control directive and shall contain the binary value ‘010’ for the SET RECEIVER PARAMETERS directive.

A1.4.3 Receiver Frequency

A1.4.3.1 General

Bits 10–12 of the SET RECEIVER PARAMETERS directive shall be used to set the Receiver frequency to the desired value.

A1.4.3.2 Forward Link

In the context of the forward link, this three-bit field shall define the forward frequency channel component. Actual frequency assignments are given in the physical layer (see annex F).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch1F	Ch2F	Ch3F	Ch4F	Ch5F	Ch6F	Ch7F	Ch8F

A1.4.3.3 Return Link

In the context of the return link, this three-bit field shall define the return frequency channel component. Actual frequency assignments are given in the physical layer (see annex F).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch1R	Ch2R	Ch3R	Ch4R	Ch5R	Ch6R	Ch7R	Ch8R

A1.4.4 Receiver Data Decoding

Bits 8–9 of the SET RECEIVER PARAMETERS directive shall contain the following coding options:

‘00’ = Reserved;

‘01’ = Convolutional Code(7,1/2) (G2 vector inverted) with attached CRC-32;

‘10’ = Uncoded with attached CRC-32;

‘11’ = Reserved.

A1.4.5 Receiver Modulation

Bit 7 of the SET RECEIVER PARAMETERS directive shall contain the following transmission modulation options:

a) ‘1’ =Non-coherent PSK;

b) ‘0’ = Coherent PSK.

A1.4.6 Receiver Data Rate

A1.4.6.1 Bits 3–6 of the SET RECEIVER PARAMETERS directive shall contain one of the following receiver data rates (rates in kbps, i.e., powers of 10).

NOTE – Because of the NASA 2001 Mars Odyssey implementation, there is an added constraint on the use of the values in the Data Rate field for 8, 32, 128, and 256 Kbps. Data rate selection is linked to the modulation field value as shown in the tables below (nc indicates non-coherent, and c indicates coherent). R1 through R4 indicates the field is reserved for future definition by the CCSDS.

A1.4.6.2 Ordered by Data Rate:

‘1000’	‘1001’	‘0000’	‘0001’	‘1100’	‘0010’	‘0011’	‘1101’	‘0100’	‘0101’	‘0110’	‘0111’	‘1010’	‘1011’	‘1110’	‘1111’
2	4	8 NC	8 C	16	32 NC	32 C	64	128 NC	128 C	256 NC	256 C	R1	R2	R3	R4

A1.4.6.3 Ordered by Bit pattern:

‘0000’	‘0001’	‘0010’	‘0011’	‘0100’	‘0101’	‘0110’	‘0111’	‘1000’	‘1001’	‘1010’	‘1011’	‘1100’	‘1101’	‘1110’	‘1111’
8 NC	8 C	32 NC	32 C	128 NC	128 C	256 NC	256 C	2	4	R1	R2	16	64	R3	R4

A1.4.7 Receiver Mode

Bits 0–2 of the SET RECEIVER PARAMETERS directive shall contain the Receiver Mode options. Bit pattern assignments shall be defined in the MIB.

A1.5 SET V(R) DIRECTIVE

A1.5.1 Overview

The SET V(R) directive shall consist of four fields, positioned contiguously, in the following sequence:

a) Directive Type (3 bits);

b) PCID (1 bit);

c) Spare (4 bits);

d) Receiver Frame Sequence Number (SEQ_CTRL_FSN) (8 bits).

NOTE – The structural components of the SET V(R) directive are shown in figure A-5.

Bit 0 ... Bit 15

Receiver Frame Sequence Number SEQ_CTRL_FSN 8 bits	Spare 4 bits	PCID 1 bits	Directive Type 3 bits
0,1,2,3,4,5,6,7	8,9,10,11	12	13,14,15

Figure A-5: SET V(R) Directive

A1.5.2 Directive Type

A1.5.2.1 Bits 13–15 of the SET V(R) directive shall contain the Directive Type.

A1.5.2.2 The three-bit Directive Type field shall identify the type of protocol control directive and shall contain the binary value ‘011’ to identify the SET V(R) directive.

A1.5.3 PCID

Bit 2 of the SET V(R) directive shall contain the PCID associated with the receiver Frame Sequence Number (SEQ_CTRL_FSN).

A1.5.4 Spare

Bits 8–11 of the SET V(R) directive shall contain spare bits.

A1.5.5 Receiver Frame Sequence Number

Bits 0–7 of the SET V(R) directive shall contain the value of the Frame Sequence Number (SEQ_CTRL_FSN) to which the receiving unit is to be set.

A1.6 REPORT REQUEST DIRECTIVE

A1.6.1 Overview

The REPORT REQUEST directive is the mechanism by which either 1) a status report or 2) a time-tag, or 3) a PLCW per PCID can be requested of a sender or responder. It shall consist of seven fields, positioned contiguously, in the following sequence:

a) Directive Type (three bits);

b) PCID 1 PLCW Request (one bit);

c) PCID 0 PLCW Request (one bit);

d) Time-Tag Request (three bits);

e) Status Request (five bits);

f) Spare (five bits).

NOTE – The structural components of the REPORT REQUEST directive are shown in figure A-6.

Bit 0 ... Bit 15

Spare 3 bits	Status Report Request 5 bits	Time-Tag Request 3 bit	PCID 0 PLCW Request 1 bit	PCID 1 PLCW Request 1 bit	Directive Type 3 bits
0,1,2	3,4,5,6,7	8,9,10	11	12	13,14,15

Figure A-6: Report Request

A1.6.2 Directive Type

A1.6.2.1 Bits 13–15 of the REPORT REQUEST directive shall contain the Directive Type.

A1.6.2.2 The three-bit Directive Type field shall identify the type of protocol control directive and shall contain the binary value ‘100’.

A1.6.3 Proximity Channel 1 PLCW Report Request Field

Bit 12 of the REPORT REQUEST directive shall indicate whether a PLCW report for PC1 is required:

a) ‘1’ = PLCW report is needed for PC1;

b) ‘0’ = PLCW report is not required.

A1.6.4 Proximity Channel 0 PLCW Report Request Field

Bit 11 of the REPORT REQUEST directive shall indicate whether a PLCW report for PC0 is required:

a) ‘1’ = PLCW report is needed for PC0;

b) ‘0’ = PLCW report is not required.

A1.6.5 Time-Tag Request Field

Bits 8–10 of the directive, if set to a value other than ‘000’, shall indicate a request to the remote transceiver to initiate a Proximity-1 time tag exchange (see section 5).

A1.6.6 Status Report Request

A1.6.6.1 The value contained in bits 3–7 of the REPORT REQUEST directive shall indicate the type of status report desired.

A1.6.6.2 If set to ‘00000’, a status report is not required.

A1.6.6.3 The types of status reports are reserved for CCSDS use.

A1.6.7 Spares

Bits 0–3 of the REPORT REQUEST directive shall contain spare bits set to 'all zero'.

A1.7 PROXIMITY LINK CONTROL WORD (PLCW)

A1.7.1 Overview

The Proximity Link Control Word (PLCW) shall consist of five fields, positioned contiguously, in the following sequence:

a) Directive Type (three bits);

b) Retransmit Flag (one bit);

c) PCID (one bit);

d) Expedited Frame Counter (three bits);

e) Report Value (eight bits).

NOTE – The structural components of the PLCW are shown in figure A-7. This format only applies to PLCWs contained within variable-length SPDUs.

Bit 0 … Bit 15

Report Value (SEQ_FSN)	Expedited Frame Counter	PCID	Retransmit Flag	Directive Type
8 bits	3 bits	1 bit	1 bit	3 bits

Figure A-7: Proximity Link Control Word

NOTE – It is mandatory to transmit the PLCW using the Expedited Quality of Service.

A1.7.2 Directive Type

A1.7.2.1 Bits 13–15 of the PLCW shall contain the Directive Type.

A1.7.2.2 The three-bit Directive Type field shall identify the type of protocol report and shall contain the binary value '101'.

A1.7.3 PLCW RETRANSMIT FLAG

A1.7.3.1 Bit 12 of the PLCW shall contain the PLCW Retransmit Flag.

A1.7.3.2 A setting of ‘0’ in the PLCW Retransmit Flag shall indicate that there are no outstanding frame rejections in the sequence received so far, and thus retransmissions are not required.

A1.7.3.3 A setting of ‘1’ in the PLCW Retransmit Flag shall indicate that a received frame failed a frame acceptance check and, therefore, that a retransmission of that frame is required.

A1.7.4 Proximity Channel Identification

A1.7.4.1 Bit 11 of the PLCW shall contain the PCID field.

A1.7.4.2 The one-bit PCID field shall contain the PCID of the Physical Channel with which this report is associated.

NOTE – Each PCID in use has its own PLCW reporting activated.

A1.7.5 Expedited Frame Counter

A1.7.5.1 Bits 8-10 of the PLCW shall contain the Expedited Frame Counter.

A1.7.5.2 The Expedited Frame Counter shall provide a modulo-8 counter indicating that Expedited frames have been received.

A1.7.6 Report Value

A1.7.6.1 Bits 0-7 of the PLCW shall contain the Report Value.

A1.7.6.2 The Report Value field shall contain the next sequence controlled Frame Sequence Number (SEQ_FSN).

A1.7.6.3 Separate Report Values shall be maintained for each PC independent of the I/O port.

A1.8 STATUS REPORT

A1.8.1 Overview

The STATUS REPORT is the mechanism by which status is transferred across the proximity link from the local transceiver to the remote transceiver.

a) Directive Type (three bits);

b) Report Type (two bits);

c) Status Content (eleven bits).

NOTE – The structural components of the STATUS REPORT are shown in figure A-8.

Bit 0 Status Content 11 bits	Report Type 2 bits	Directive Type 3 bits Bit 15
0,1,2,3,4,5,6,7,8,9,10	11,12	13,14,15

Figure A-8: Status Report

A1.8.2 Directive Type

A1.8.2.1 Bits 13–15 of the STATUS REPORT shall contain the Directive Type.

A1.8.2.2 The three-bit Directive Type field shall identify the type of protocol report and shall contain the binary value ‘110’.

A1.8.3 Report Type

Bits 11-12 of the STATUS REPORT shall indicate the type of status report to be transmitted: These values are Reserved for CCSDS Use.

A1.8.4 Status Content

Bit 0-10 of the STATUS REPORT directive shall contain the status information.

A1.9 REPORT SOURCE SPACECRAFT ID

A1.9.1 Overview

The REPORT SOURCE SPACECRAFT ID is the mechanism by which the local transceiver can provide status of its source spacecraft ID to the remote transceiver across the proximity link.

a) Directive Type (three bits);

b) Reserved (three bits);

c) Source Spacecraft ID (ten bits).

NOTE – The structural components of the REPORT SOURCE SPACECRAFT ID are shown in figure A-9.

Bit 0		Bit 15
Source Spacecraft ID 10 bits	Reserved 3 bits	Directive Type 3 bits
0,1,2,3,4,5,6,7,8,9	10,11,12	13,14,15

Figure A-9: Report Source Spacecraft ID

A1.9.2 Directive Type

A1.9.2.1 Bits 13–15 of the REPORT SOURCE SPACECRAFT ID status report shall contain the Directive Type.

A1.9.2.2 The three-bit Directive Type field shall identify the type of status report and shall contain the binary value ‘111’.

A1.9.3 Reserved

Bits 10–12 of the REPORT SOURCE SPACECRAFT ID status report shall contain reserved bits.

A1.9.4 Spacecraft ID

Bits 0-9 of the REPORT SOURCE SPACECRAFT ID status report shall contain the Spacecraft ID of the source of the transfer frame.

A2 TIME DISTRIBUTION DATA FIELD

NOTE – See table 3-4 for a complete overview of the variable-length SPDU structure including the SPDU header and SPDU data field.

A2.1 OVERVIEW

The Time Distribution SPDU Data Field is the container that describes both the type and value of the time entity for distribution.

A single Time Distribution directive shall be contained within a Time Distribution SPDU.

The format of the TIME DISTRIBUTION SPDU Data Field shall consist of two fields, positioned contiguously, in the following sequence:

a) Time Distribution directive type (1 octet);

b) Time field (variable: 1 to 14 octets).

NOTE – The structural components of the TIME DISTRIBUTION SPDU Data Field are shown in figure A-10.

Octet: 0	Min: Octet 1 Max: Octet 14
TIME DISTRIBUTION Directive Type 1 octet	Time Field Variable: 1 to 14 octets

Figure A-10: Time Distribution SPDU Data Field Format

A2.2 TIME DISTRIBUTION DIRECTIVE TYPE

A2.2.1 Octet 0 of the TIME DISTRIBUTION SPDU Data Field shall contain the time distribution directive type field indicating the function to be performed (if any) with the time contents.

A2.2.2 Time Distribution Types are:

a) ‘00000000’ = NULL;

b) ‘00000001’ = TRANSFER UTC TIME;

c) ‘00000010’ = BROADCAST SPACECRAFT CLOCK TIME;

d) all others = Reserved for CCSDS Use.

A2.3 TIME FIELD

Octet 1 through Octet 14 shall contain the time value associated with the directive. The time code selected for this field shall comply with the CCSDS Time Code Format Recommendation (reference [8]).

ANNEX B

MANAGEMENT INFORMATION BASE (MIB) PARAMETERS

(This annex **is** part of the Recommendation.)

This table lists each MIB parameter in the document along with how it is used and in what layer (if a Physical layer parameter) or sublayer (if a Data Link layer parameter) it appears. Values for the Layer field are: P = Physical, C = C&S, F = Frame, M = MAC, D = Data Services, I = I/O.

Parameter	Comment	Layer
Acquisition_Idle_Duration	Mandatory. Used in the Link Establishment Procedure. Session static.	M
ASM_Bit_Error_Tolerance	Mandatory for synchronous data links. Used in the frame synchronization process. Session static.	C
Carrier_Loss_Timer_Underflow	Mandatory. Maximum value of CARRIER_LOSS_TIMER. Session static.	M,D
Carrier_Only_Duration	Mandatory. Used in the Link Establishment Procedure. Session static.	M
Remote_Spacecraft_ID	Mandatory. Used to address one or several remote spacecraft as opposed to the local spacecraft. Session dynamic.	M
Hail_Waiting_Period	Mandatory. Used in the Hail Activity. Session static.	M
Hail_Response	Mandatory. The acknowledgement by the responder that the persistent activity has been accepted. In this case, a valid transfer frame. Session static.	M
Hail_Notification	Mandatory. The message provided to the local vehicle controller, e.g., spacecraft C&DH by the caller and responder upon success or failure of the persistent activity. Session static.	M

Parameter	Comment	Layer
Hail_Lifetime	Mandatory. The time period during which the persistent activity shall be repeated until the MAC detects the expected Hail_Response. The Hail_Lifetime can be locally defined in terms of a duration or a maximum number of times. This activity shall be repeated before the activity is aborted. Session static.	M
Hailing_Channel	Mandatory. Channel assignment used in the Hail Activity during Link Establishment. Session static.	M
Hailing_Data_Rate	Mandatory. Default data rate used in the Hail Activity during Link Establishment. Session static.	M
Interval_Clock	Mandatory. A frequency (e.g., 100 Hz) that is used for interval timing. Session static.	C
Max_Size_PLTU_Received	Mandatory for synchronous data links. Used in the frame synchronization process. Session static.	C
Maximum_Packet_Size	Mandatory if packets are used. Maximum size of a packet in octets. Used in the segmentation process. Session static.	F,I
PLCW_Repeat	Mandatory. Defines the maximum amount of transmit time between PLCWs. Session static.	D
Receive_Duration	Mandatory. Defines the maximum amount of time a receiver anticipates the partnered transceiver will transmit in half duplex operations. Session static.	M
Receiver_Mode	Optional. Used in the Set Receiver Parameters Directive. Enterprise-specific. Session static.	M
Receiving_PCID	Mandatory. When the PCID is used to address a physical transceiver, defines the expected value of the PCID on the receive side.	F

Parameter	Comment	Layer
Resync_Local	Mandatory. It is the responsibility of the local controller to decide how synchronization will be re-established, if Resync_Local equals *false*. Otherwise, the Sender Node's FOP-P forces synchronization by sending the SET V(R) directive.	D
Send_Duration	Mandatory. Defines the maximum transmit time in half duplex operations. Session static.	M
Synch_Timeout	Mandatory. Defines the value the Sync_Timer is initialized or reinitialized to. Session dynamic.	D
Local_Spacecraft_ID	Mandatory. The spacecraft ID of the local Proximity-1 spacecraft, as opposed to the remote spacecraft partner. Session static.	M
Test_Source	Mandatory. Used in the verification of the spacecraft ID when the source/destination ID is source.	F
Tail_Idle_Duration	Mandatory. Used in the Link Establishment Procedure. Session static.	M
Transmission_Mode	Optional. Used in the Set Transmitter Parameters Directive. Enterprise specific. Session static.	M
Transmission_Window	Mandatory. Sets the maximum size of the transmission window for the COP-P. Session static.	D
Transmit_Channel_Coding	Mandatory. Defines the channel coding used: convolutional or uncoded. Session static.	P

ANNEX C
MARS SURVEYOR PROJECT 2001 ODYSSEY ORBITER PROXIMITY SPACE LINK CAPABILITIES

(This annex is **not** part of the Recommendation.)

NOTE – The following capability is being used by the Mars Surveyor Project '01 Odyssey Orbiter and is being provided for information only.

C1 TONE BEACON MODE

C1.1 The Tone Beacon Mode configures the transceiver to transmit a CW tone. This mode can be used to signal microprobes to transmit their data to the orbiter. Addressing of multiple microprobes is accomplished by using four unique CW frequencies. Microprobes can respond in any transmit configuration compatible with valid orbiter receive configurations.

C1.2 The four orbiter CW beacon frequencies are:

a) 437.1000 MHz;

b) 440.7425 MHz;

c) 444.3850 MHz;

d) 448.0275 MHz.

C1.3 The lander CW beacon frequency is 401.585625.

C1.4 The Tone Beacon Mode can be used to perform Doppler measurements. The orbiter can provide a CW tone at 437.1 MHz and the lander can coherently transpond with the CW tone at 401.585625 MHz.

C2 TRANSMIT STANDBY MODE

Transmit Standby mode prevents the transceiver from transmitting. This is the default mode when multiple landed elements are within the field of view of an orbiter hailing. It prevents interference caused by several landed elements responding simultaneously.

C3 CONVOLUTIONAL CODE IMPLEMENTATION

The rate 1/2, constraint-length 7 convolutional code employed does not contain symbol inversion on the output path of connection vector G2 as specified in reference [6]. In order to be compatible with the Mars '01 orbiter, implementations will need to set the encoding data parameter field of the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS directives as indicated in C4 in the directives below.

C4 DIRECTIVE AND PROTOCOL DATA UNITS

C4.1 SET TRANSMITTER PARAMETERS DIRECTIVE

C4.1.1 Overview

The SET TRANSMITTER PARAMETERS directive shall consist of six fields, positioned contiguously, in the following sequence:

a) Transmission (TX) Mode (three bits);

b) Transmission Data Rate (four bits);

c) Transmission Modulation (one bit);

d) Transmission Data Encoding (two bits);

e) Transmission Frequency (three bits);

f) Set Directive Type (three bits).

NOTE – The structural components of the SET TRANSMITTER PARAMETERS directive are shown in figure C-1.

Bit 0 ... Bit 15

TX Mode 3 bits	TX Data Rate 4 bits	TX Modulation 1 bit	TX Data encoding 2 bits	TX Frequency 3 bits	Set Directive Type 3 bits
0,1,2	3,4,5,6	7	8,9	10,11,12	13,14,15

Figure C-1: Mars Surveyor Project 2001 SET TRANSMITTER PARAMETERS Directive

C4.1.2 Set Directive Type

C4.1.2.1 Bits 13–15 of the SET TRANSMITTER PARAMETERS directive shall contain the Set Directive Type.

C4.1.2.2 The three-bit Set Directive Type field shall identify the type of protocol control directive and shall contain the binary value ‘000’ for the SET TRANSMITTER PARAMETERS directive.

C4.1.3 Transmission Frequency

C4.1.3.1 Bits 10–12 of the SET TRANSMITTER PARAMETERS directive shall be used to set the transmitter frequency to the desired value.

C4.1.3.2 In the context of the forward link, this three-bit field shall contain the value '000' indicating that the hailing return frequency, 401.585625 MHz, shall be used. In the context of the return link, this three-bit field shall contain the value '010' indicating 437.1 MHz.

C4.1.4 Transmission Data Encoding

Bits 8–9 of the SET TRANSMITTER PARAMETERS directive shall contain the following coding options:

a) '00' =N/A;

b) '01' = Convolutional Code (7,1/2) without G2 Inverter (CRC-32 attached);

c) '10' = Uncoded (CRC-32 attached);

d) '11' =N/A.

C4.1.5 Transmission Modulation

Bit 7 of the SET TRANSMITTER PARAMETERS directive shall contain the transmission modulation options:

a) '1' = PSK;

b) '0' = PSK Coherent.

C4.1.6 Transmission Data Rate

C4.1.6.1 Bits 3–6 of the SET TRANSMITTER PARAMETERS directive shall contain the transmission data rate.

'0000'	'0001'	'0010'	'0011'	'0100'	'0101'	'0110'	'0111'	'1000'	'1001'	'1010'	'1011'	'1100'	'1101'	'1110'	'1111'
8 NC	8 C	32 NC	32 C	128 NC	128 C	256 NC	256 C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

NOTE – Rates are in kbps, i.e., powers of 10; C indicates PSK coherent modulation, and NC indicates PSK non-coherent modulation.

C4.1.7 Transmission Mode

C4.1.7.1 Bits 0–2 of the SET TRANSMITTER PARAMETERS directive shall contain the Transmission Mode options.

C4.1.7.2 Bit pattern assignments shall be defined in the MIB.

C4.2 SET RECEIVER PARAMETERS DIRECTIVE

C4.2.1 Overview

The SET RECEIVER PARAMETERS directive shall consist of six fields, positioned contiguously, in the following sequence:

a) Receiver (RX) Mode (three bits);

b) Receiver Data Rate (four bits);

c) Receiver Modulation (one bit);

d) Receiver Data Encoding (two bits);

e) Receiver Frequency (three bits);

f) Set Directive Type (three bits).

NOTE – The structural components of the SET RECEIVER PARAMETERS directive are shown in figure C-2.

Bit 0 … Bit 15

RX Mode 3 bits	RX Rate 4 bits	RX Modulation 1 bit	RX Data Encoding 2 bits	RX Frequency 3 bits	Set Directive Type 3 bits
0,1,2	3,4,5,6	7	8,9	10.11,12	13,14,15

Figure C-2: Mars Surveyor Project 2001 SET RECEIVER PARAMETERS Directive

C4.2.2 Set Directive Type

C4.2.2.1 Bits 13–15 of the SET RECEIVER PARAMETERS directive shall contain the Directive Type.

C4.2.2.2 The three-bit Set Directive Type field shall identify the type of protocol control directive and shall contain the binary value ‘010’ for the SET RECEIVER PARAMETERS directive.

C4.2.3 Receiver Frequency

C4.2.3.1 Bits 10–12 of the SET RECEIVER PARAMETERS directive shall be used to set the receiver frequency to the desired value.

C4.2.3.2 In the context of the forward link, this three-bit field shall contain the value ‘010’ indicating that the hailing forward frequency, 437.1 MHz, shall be used. In the context of the return link, this three-bit field shall contain the value ‘000’ indicating 401.585625 MHz.

C4.2.4 Receiver Data Encoding

Bits 8–9 of the SET RECEIVER PARAMETERS directive shall contain the following coding options:

a) ‘00’ = N/A;

b) ‘01’ = Convolutional Code (7,1/2) without G2 Inverter (CRC-32 attached);

c) ‘10’ = Uncoded (CRC-32 attached);

d) ‘11’ = N/A.

C4.2.5 Receiver Modulation

Bit 7 of the SET RECEIVER PARAMETERS directive shall contain the transmission modulation options:

a) ‘1’ = PSK;

b) ‘0’ = PSK Coherent.

C4.2.6 Receiver Data Rate

Bits 3–6 of the SET RECEIVER PARAMETERS directive shall contain the Receiver Data Rate.

‘0000’	‘0001’	‘0010’	‘0011’	‘0100’	‘0101’	‘0110’	‘0111’	‘1000’	‘1001’	‘1010’	‘1011’	‘1100’	‘1101’	‘1110’	‘1111’
8 NC	8 C	32 NC	32 C	128 NC	128 C	256 NC	256 C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

NOTE – Rates are in kbps, i.e., powers of 10; C indicates PSK coherent modulation, and NC indicates PSK non-coherent modulation.

C4.2.7 Receiver Mode

Bits 0–2 of the SET RECEIVER PARAMETERS directive shall contain the Receiver Mode options.

ANNEX D

CRC-32 CODING PROCEDURES

(This annex **is** part of the Recommendation.)

D1 CRC-32 ENCODING PROCEDURE

D1.1 The **ENCODING PROCEDURE** accepts an n-bit **TRANSFER FRAME**, excluding the **CYCLIC REDUNDANCY CHECK**, and generates a systematic binary (n+32,n) block code by appending a 32-bit **CYCLIC REDUNDANCY CHECK** (CRC-32) as the final 32 bits of the codeblock.

D1.2 If $M(X) = m_{n-1}X^{n-1} + \cdots + m_0X^0$ is the n-bit message (**TRANSFER FRAME**) expressed as a polynomial with binary coefficients, then the equation for the 32-bit **CYCLIC REDUNDANCY CHECK**, expressed as a polynomial $R(X) = r_{31}X^{31} + \cdots + r_0X^0$ with binary coefficients, is:

$$R(X) = [X^{32} M(X)] \text{ modulo } G(X)$$

where $G(X)$ is the generating polynomial given by:

$$G(X) = X^{32} + X^{23} + X^{21} + X^{11} + X^2 + 1$$

D1.3 The (n+32)-bit CRC-32-encoded block, expressed as a polynomial $C(X) = c_{n+31}X^{n+31} + \cdots + c_0X^0$ with binary coefficients, is:

$$C(X) = X^{32} M(X) + R(X)$$

The shift register is preset to the all '0' state prior to encoding.

The n bits of the message are input in the order $m_{n-1},\ldots,m_0$, and the (n+32) bits of the codeblock are output in the order $c_{n+31},\ldots,c_0 = m_{n-1},\ldots,m_0, r_{31},\ldots, r_0$.

NOTE – A possible implementation of an encoder is described in figure D-1.

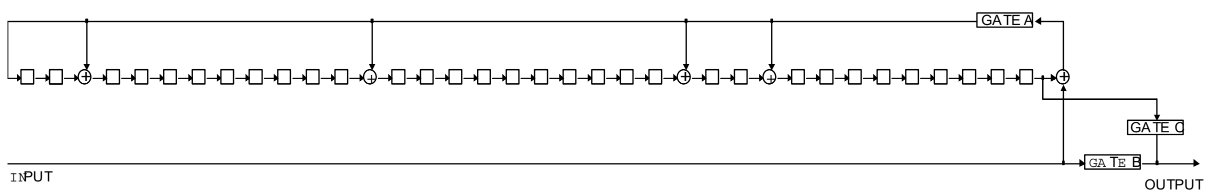


Figure D-1: A Possible Implementation of the Encoder

NOTE – Figure D-1 shows an arrangement for encoding using the shift register. To encode, the storage stages are set to ‘zero’, gates A and B are enabled (closed), gate C is inhibited (open), and *n* message bits are clocked into the input. They will appear simultaneously at the output. After the bits have been entered, the output of gate A is clamped to ‘zero’, gate B is inhibited, gate C is enabled, and the register is clocked a further 32 counts. During these counts the required check bits will appear in succession at the output.

D2 CRC-32 DECODING PROCEDURE

D2.1 The **DECODING PROCEDURE** accepts an (n+32)-bit received **codeblock**, including the 32-bit **CYCLIC REDUNDANCY CHECK**, and generates a 32-bit syndrome. An error is detected if and only if at least one of the syndrome bits is non-‘zero’.

D2.2 If $C^*(X) = c^*_{n+31} X^{n+31} + \cdots + c^*_0 X^0$ is the (n+32)-bit received **codeblock**, expressed as a polynomial with binary coefficients, then the equation for the 32-bit **syndrome**, expressed as a polynomial $S(X) = s_{31}X^{31} + \cdots + s_0X^0$ with binary coefficients, is:

$$S(X) = [X^{32}\, C^*(X)] \text{ modulo } G(X)$$

The syndrome polynomial will be zero if no error is detected, and nonzero if an error is detected.

D2.3 The received block $C^*(X)$ equals the codeblock $C(X)$ plus (modulo two) the (n+32)-bit error block $E(X)$, $C^*(X) = C(X) + E(X)$, where both are expressed as polynomials of the same form i.e., $C(X) = c^*_{n+31} X^{n+31} + \cdots + c^*_0 X^0$ with binary coefficients.

NOTE – A possible implementation of a decoder is described in figure D-2.

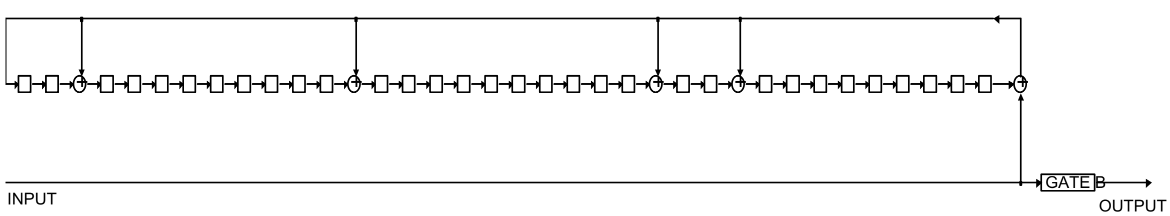


Figure D-2: A Possible Implementation of the Decoder

NOTE – Figure D-2 shows an arrangement for decoding using the shift register. To decode, the storage stages are set to ‘zero’ and gate B is enabled. The first *n* bits (message bits) of the (n+32) received bits are then clocked into the input. After *n* counts, gate B is inhibited, the 32 remaining received bits (check bits) are then clocked into the input, and the contents of the storage stages are then examined. For an error-free codeblock, the contents will be ‘zero’. A non-‘zero’ content indicates an erroneous codeblock.

ANNEX E

NOTIFICATIONS TO VEHICLE CONTROLLER

This table summarizes all of the conditions throughout the document under which the vehicle controller is notified from within the protocol.

Number	CONDITION	REFERENCE
1	RESULT OF PERSISTENT ACTIVITY Notification of the success or failure of a persistent activity.	See subsection 4.3.2.1
2	STATE CONTROL STATUS Status of the proximity-1 State Control Variables	See Section 6, State Tables
3	INVALID FRAME SOURCE When the SCID field and RECEIVING_SCID_BUFFER disagree, and TEST_SOURCE is true, then a session violation has occurred and the vehicle controller shall be notified.	See subsection 6.7
4	TIMING SERVICES INSTANCE At the end of receiving the SET CONTROL PARAMETERS (time sample) directives, the recipient transceiver notifies it's vehicle controller that proximity time tags and frame sequence numbers are available.	See subsection 5.1
5	NO CARRIER – HALF DUPLEX	State Table 6-11, Event 51
6	NO DATA TRANSFERRED – HALF DUPLEX	State Table 6-11, Event 48
7	DATA ACTIVITY LONGER THAN EXPECTED – HALF DUPLEX	State Table 6-11, Event 45
8	COP-P LOSS OF SYNCHRONIZATION	See subsection 7.1.3.1

	When FOP-P detects out-of-synchronization condition and Resync_Local = false	

ANNEX F
PHYSICAL LAYER

F1 GENERAL REQUIREMENTS FOR THE PHYSICAL LAYER

F1.1 The Proximity-1 Link system shall be capable of supporting the communication and navigation needs between a variety of network elements, e.g., orbiters, landers, rovers, microprobes, balloons, aerobots, gliders.

NOTE – The categories of network elements (E1, E2,…) are listed in table F-1.

F1.2 E2 landed elements (noted E2c) for which range and range-rate measurements are needed shall have TX/RX frequency coherency capability.

Table F-1: Categories of Radio Equipment Contained on Proximity-1 Link Elements

Category	Description
E1:	Elements with transmit-only capability.
E2:	Elements with transmit and receive capability.
E2n:	E2 elements with non-coherent mode only.
E2c:	E2 elements offering in addition transmit-receive frequency coherency capability.
E2d:	E2 elements with a descoped receiver capable of receiving an FSK modulated carrier. These elements transmit using PSK modulation.
NOTE – E2d radio equipment is intended to be used in microprobes.	

F2 FUNCTIONAL REQUIREMENTS

F2.1 DISCUSSION

The prime function of the Physical layer is to establish a communications channel upon which the data can flow. This process includes configuration of the following physical layer parameters: frequency, polarization, modulation, acquisition and idle sequence, data rates, and convolutional coding such that common operating characteristics exist in both communicating entities.

F2.2 GENERAL REQUIREMENTS

In order to enable a physical channel connection, the physical layer shall go through a series of actions to establish a communication channel. The transmitter shall vary its initial modulation to optimize the recipient receiver's ability to acquire the channel.

F2.3 CHANNEL CONNECTION PROCESSES

F2.3.1 General Requirements

F2.3.1.1 The Physical layer shall accept operational control signals from, and provide operational status to the Data Link layer.

NOTE – The MAC sublayer provides the MODE, TRANSMIT and DUPLEX parameters that control the operational state of the receiver and transmitter.

F2.3.1.2 The Physical layer shall, as required, sequence its modulation from *off* to *carrier_only* to *data_modulation* in order to establish a data channel with a communications partner preceding the transfer of data.

F2.3.1.3 The receiving portion of the transceiver shall sweep the frequency channel to which it is assigned in order to acquire lock at an assigned frequency channel:

a) the receiver shall first attempt to lock to the carrier;

b) the internal state of the physical channel connection shall be tracked in the *Connection* variable.

NOTE – During this process, the receiver status is provided to the MAC sublayer of the Data Link layer. This status is provided by two interlayer signals: **Carrier_Acquired** and **Bit_In_Lock_Status**.

F2.3.2 Send Side Signals

F2.3.2.1 CARRIER_ACQUIRED

The **Carrier_Acquired** signal shall notify the MAC sublayer that the receiver has acquired a carrier signal. The **Carrier_Acquired** signal shall be set to *true* when the receiver is locked to the received RF signal and *false* when not in lock.

F2.3.2.2 BIT_IN_LOCK_STATUS

The **Bit_In_Lock_Status** signal shall be used to notify the MAC sublayer that bit synchronization has been acquired, and the received serial bit stream is being provided to the C&S sublayer by the Physical layer. The **Bit_In_Lock_Status** signal shall be set to *true* when the receiver is confident that its bit detection processes are synchronized to the modulated bit stream and the bits output are of an acceptable quality for processing by the Data Link layer. It shall be set to *false* when the receiver is not in bit lock.

F2.3.2.3 OUTPUT_BIT_CLOCK

The OUTPUT_BIT_CLOCK is the clock signal provided by the physical layer to the C&S sublayer to clock out the PLTU whenever a PLTU is ready for transmission.

F2.3.2.4 RF_OUT

RF_OUT represents all of the possible signal outputs to the communication partner from the physical layer in the model. These consist of: *off* (no signal), *carrier_only*, *idle_data*, and *pltu_data*.

F2.3.3 Receive Side Signals

F2.3.3.1 RECEIVED BIT CLOCK/DATA BITS

The RECEIVED BIT CLOCK/DATA BITS is the clock signal and data provided by the physical layer from the coding and synchronization sublayer.

F2.3.3.2 DOPPLER MEASUREMENTS

The DOPPLER MEASUREMENTS are Doppler samples calculated within the transceiver.

F2.3.3.3 RF_IN

RF_IN represents all of the possible signal inputs into the physical layer in the model of the communication partner. These consist of: *off* (no signal) *carrier_only*, *idle_data*, and *pltu_data.*

F2.3.4 Physical Layer Internal Variables

F2.3.4.1 CONNECTION

The CONNECTION state physical layer variable tracks the internal state of the physical layer of the given transceiver's physical connection to a communication partner. It takes on the values: *open*, *acquire_carrier*, *acquire_idle*, *tail_idle*, *closed*. See the Physical Layer State Table (table G-1).

F2.3.4.2 Receiver State

The states of the receiver are: *on*, *standby*, *off*.

F2.3.4.3 Transmitter State

The states of the transmitter are: *asynchronous*, *synchronous*, *standby*, *off*.

F2.3.4.4 Physical Layer State Table

See annex G for a comprehensive description of the Physical Layer State Table.

F3 IDLE DATA

F3.1 GENERAL

A specific Pseudo-noise (PN) sequence of data bits defines the bit pattern used for all the functions that Idle data performs for the Proximity link. Idle data is required for data acquisition, the Idle sequence (Idle interjected between PLTUs) and the tail sequence. In all cases, it consists of the repeating PN 352EF853 (in hexadecimal). Idle data can start on any bit within the PN sequence. However the continuum of idle bits shall follow the defined PN sequence (partially or redundantly as required).

NOTE – When the convolutional code is applied, all transmitted bits including the Idle data shall be convolutionally encoded.

F3.2 ACQUISITION SEQUENCE

The Physical layer shall provide the modulation necessary for the partners in a session to acquire and process each other's transmission. When transmission commences, the transmitter's modulation shall be sequenced (first carrier only then idle bits) such that the receiving unit can acquire the signal, achieve a reliable symbol stream and pre-condition the Convolutional decoder (when selected) in preparation for acceptance of the transmitted data units.

F3.3 IDLE SEQUENCE

During the data services phase, the physical channel operates in a synchronous channel mode where a continuous stream of bits is sent from the transmitter to the receiver. In asynchronous data link operations, the Data Link layer provides PLTUs intermittently for transfer. During the periods when no PLTU is ready for transfer, the Physical layer shall inject the Idle sequence into the channel in order to keep the stream flowing.

F3.4 TAIL SEQUENCE

Prior to terminating transmission (removing modulation) the transmitter may be required to transmit a series of idle bits (tail sequence) for a fixed period in order for the receiving unit to process the received data unit fully (for convolutional decoding and bit lock assurances).

F3.5 PHYSICAL CONNECTION PROCESS MIB PARAMETERS

F3.5.1 Carrier_Only_Duration

The Carrier_Only_Duration MIB parameter contains the amount of time the acquisition process will transmit a carrier only signal.

F3.5.2 Acquisition_Idle_Duration

The Acquisition_Idle_Duration MIB parameter contains the number of idle bits that need to be sent in the acquisition process.

F3.5.3 Tail_Idle_Duration

The Tail_Idle_Duration MIB parameter contains the number of idle bits that need to be sent in the tail process prior to extinguishing the transmitted output signal.

F3.5.4 Transmit_Channel_Coding

The Transmit_Channel_Coding MIB parameter controls the coding for the transmitted channel. It has two values: Convolutionally Coded or Uncoded.

F4 CONTROLLED COMMUNICATIONS CHANNEL PROPERTIES

NOTES

1 This draft Recommendation is designed primarily for use in a Proximity link space environment far from Earth. The radio frequencies selected in this draft Recommendation are designed not to cause interference to radio communication services allocated by the Radio Regulations of the International Telecommunication Union (ITU). Note that particular precautions have to be taken to protect frequency bands allocated to Near Earth Space Research, Deep Space, and Space Research, passive.

2 The frequencies specified near 430 MHz cannot be used for this purpose in the vicinity of the Earth, and particular precautions have to be taken for equipment testing on Earth. However, by layering appropriately, provision is made to change only the physical layer by adding other frequencies (e.g., near 26 GHz) to enable the same protocol to be used in near Earth applications; in the latter case a strict compliance with the frequency allocations in the ITU Radio Regulations is mandatory.

F4.1 UHF FREQUENCIES

F4.1.1 Proximity-1 UHF Frequency Bands

F4.1.1.1 General

The UHF frequency allocation consists of 60 MHz between 390 MHz to 450 MHz. The forward frequency band is defined from 435 to 450 MHz. The return band is defined from 390 to 405 MHz. There is a 30 MHz deadband between them.

F4.1.1.2 UHF Frequency Channel Assignments

NOTES

1 Hailing is an activity that is used to establish a Proximity link with a remote vehicle. Hailing requires the use of a hailing frequency pair.

2 See Annex B for the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS directives, which are used to configure the channel assignment for the remote vehicle's transmitter and receiver for Channels 1 through 8. See the Extended SET TRANSMITTER PARAMETERS and Extended SET RECEIVER PARAMETERS directives for Channels 9 through 16 respectively.

F4.1.1.3 Hailing Channel

F4.1.1.3.1 The hailing channel is enterprise specific. The default configuration of the physical layer parameters (established by the enterprise) defines the hailing channel frequencies that enables two transceivers to initially communicate (via a demand or negotiation process) so that they can establish a configuration for the data services portion of the session.

F4.1.1.3.2 The hailing channel (Channel 1) for interoperability at UHF shall be 435.6 MHz in the forward link and 404.4 MHz in the return link (1348/47*33 turnaround ratio).

F4.1.1.3.3 If the Proximity Link radio equipment only supports a single channel (i.e., a single forward and return frequency pair), then the hailing channel shall be the same as the working channel.

F4.1.1.3.4 If the Proximity Link radio equipment supports multiple channels, then the hailing channel shall be distinct from the working channel.

NOTES

1 Hailing is bi-directional; i.e., either element can initiate hailing. Hailing is done at a low data rate and therefore is a low bandwidth activity. Channel 1 has been selected to minimize the use of UHF bandwidth.

2 Hailing is performed between transceivers that are pre-configured. Therefore it is nominally performed on the hailing channel. However if transceivers are compatibly configured, hailing can occur on an agreed-to channel.

3 See the MAC sublayer for further details of hailing in the link establishment process. There are various parameters associated with the Hail activity that are defined in the MIB. See annex B for these enterprise-specific parameters.

4 Hailing is accomplished for half and full duplex links using an asynchronous channel and an asynchronous data link.

5 It is recommended that after link establishment through hailing is accomplished, one transitions over to the working channel (if available) as soon as possible.

F4.1.1.4 Single Forward and Single Return Frequency Pairs

NOTE – Forward and return link frequencies may be coherently related or non-coherent.

F4.1.1.4.1 The following 7 additional channels (fixed single forward and return frequency pairs) are defined for Proximity-1 operations:

a) Channel 2. In the case where the system requires only one return frequency, associated with the forward 437.1 MHz frequency, the return frequency shall be 401.585625 MHz (147/160 turnaround ratio).

b) Channel 3. In the case where the system requires only one return frequency, associated with the forward 439.2 MHz frequency, the return frequency shall be 397.5 MHz (1325/24*61 turnaround ratio).

c) Channel 4. In the case where the system requires only one return frequency, associated with the forward 444.6 MHz frequency, the return frequency shall be 393.9 MHz (1313/38*39 turnaround ratio).

F4.1.1.4.2 In the case of the following 4 fixed return frequency applications, the forward frequency shall be defined within the 435 to 450 MHz band. See table F-2.

a) Channel 5: Return Frequency 401.4 MHz;

b) Channel 6: Return Frequency 402.0 MHz;

c) Channel 7: Return Frequency 402.6 MHz;

d) Channel 8: Return Frequency 403.2 MHz.

NOTE – Channels 9 through 16 are reserved for CCSDS use.

Table F-2: Proximity-1 Channel Assignments 1 through 8 (Frequencies in MHz)

Channel (Ch) Number	Forward (F) Frequency	Return (R)Frequency
1	**435.6**	**404.4**
2	**437.1**	**401.585625**
3	**439.2**	**397.5**
4	**444.6**	**393.9**
5	**Within 435 to 450**	**401.4**
6	**Within 435 to 450**	**402.0**
7	**Within 435 to 450**	**402.6**
8	**Within 435 to 450**	**403.2**

F4.1.1.5 Multiple Forward And Multiple Return Frequencies

NOTE – Forward and return link frequencies may be coherently related or non-coherent.

In the case where there is a need for one or multiple return frequencies paired with one or multiple forward frequencies, the forward frequencies shall be selected from the 435 to 450 MHz band in 20 kHz steps and the return frequencies shall be selected from 390 to 405 MHz in 20 kHz steps. These frequency pairs shall be distinct from the frequency pairs defined in Channels 1 through 8. The forward and return frequency components of Channels 9 through 16 are reserved for this purpose.

F4.2 S-BAND FREQUENCIES

These frequencies are intentionally left unspecified until a user need for them is identified.

NOTE – Users are requested to contact the CCSDS Secretariat, http://www.ccsds.org/secretariat.html, if such a need arises.

F4.3 X-BAND FREQUENCIES

These frequencies are intentionally left unspecified until a user need for them is identified.

NOTE – Users are requested to contact the CCSDS Secretariat, http://www.ccsds.org/secretariat.html, if such a need arises.

F4.4 KA-BAND FREQUENCIES

These frequencies are intentionally left unspecified until a user need for them is identified.

NOTE – Users are requested to contact the CCSDS Secretariat, http://www.ccsds.org/secretariat.html, if such a need arises.

F4.5 POLARIZATION

Both forward and return links shall operate with RHCP.

F4.6 MODULATION

F4.6.1 PCM/Bi-Phase-L/PM

F4.6.1.1 The PCM data shall be Bi-Phase-L encoded and modulated directly onto the carrier.

F4.6.1.2 Residual carrier shall be provided with modulation index of 60° ± 5%.

F4.6.1.3 The symmetry of PCM Bi-Phase-L waveforms shall be such that the mark-to-space ratio is between 0.98 and 1.02.

F4.6.1.4 A positive-going video signal shall result in an advance of the phase of the radio frequency carrier. For directly modulated Bi-phase-L waveform,

a) a symbol ‘1’ shall result in an advance of the phase of the radio frequency carrier at the beginning of the symbol interval;

b) a symbol ‘0’ shall result in a delay.

F4.7 DATA RATES

The Proximity-1 link shall support one or more of the following 12 discrete forward and return data rates, shown in bits per second: 1000, 2000, 4000, 8000, 16000, 32000, 64000, 128000, 256000, 512000, 1024000, 2048000

F4.8 CONVOLUTIONAL CODING

F4.8.1 Convolutional coding is typically a managed parameter and shall be applied conditionally to Proximity-1 links.

NOTE – The capability to include or exclude Convolutional coding in the sending side is configured using the SET TRANSMITTER PARAMETERS directive, and in the receiving side by the SET RECEIVER PARAMETERS directive.

F4.8.2 The convolutional code used shall be a rate 1/2, constraint-length 7 convolutional code as specified in reference [6].

NOTE – The convolutional encoding process does contain symbol inversion on the output path of connection vector G2.

F4.8.3 The decoding processor shall be capable of accepting soft symbols quantized to at least three bits.

F5 PERFORMANCE REQUIREMENTS

F5.1 DELIVERED BIT/SYMBOL STREAM ERROR RATE

Link margins shall be designed to provide a Bit Error Rate (BER) less than or equal to 1×10^{-6} for asynchronous links, i.e., links that do not use the R-S code. For fixed-length frame applications, link margins shall be designed to provide a Symbol Error Rate (SER) less than or equal to 1×10^{-3} for links where R-S coding is performed in the Data Link layer.

F5.2 CARRIER FREQUENCY STABILITY REQUIREMENTS

F5.2.1 The long term oscillator stability (over the life of the mission) including all effects and over all operating conditions shall be 10 ppm.

F5.2.2 The short term oscillator stability over 1 minute shall be 1 ppm.

F5.3 RESIDUAL AMPLITUDE MODULATION

Residual amplitude modulation of the phase modulated RF signal shall be less than 2% RMS.

F5.4 CARRIER PHASE NOISE

The minimum specification for the oscillator phase noise at 437.1 MHz shall be limited by the template shown in figure F-1. The figure shows normalized power in dBc (where dBc refers to the power relative to the carrier power) vs. frequency offset from the carrier in Hz.

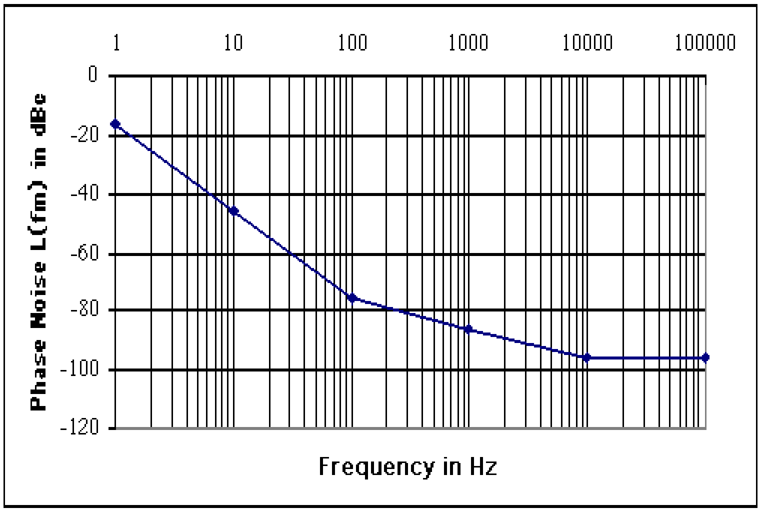


Figure F-1: Oscillator Phase Noise

NOTE – This specification is applicable for non-coherent mode only.

F5.5 OUT OF BAND SPURS

The spurious spectral lines of the transmit RF signal shall be limited by the template shown in the figure F-2. The figure shows normalized power in dBc vs. normalized frequency f/A (where A = 2*Rb) for no convolutional coding applied, but due to the Manchester code; A = 4*Rb if convolutional coding is used; Rb is the bit rate (raw data).

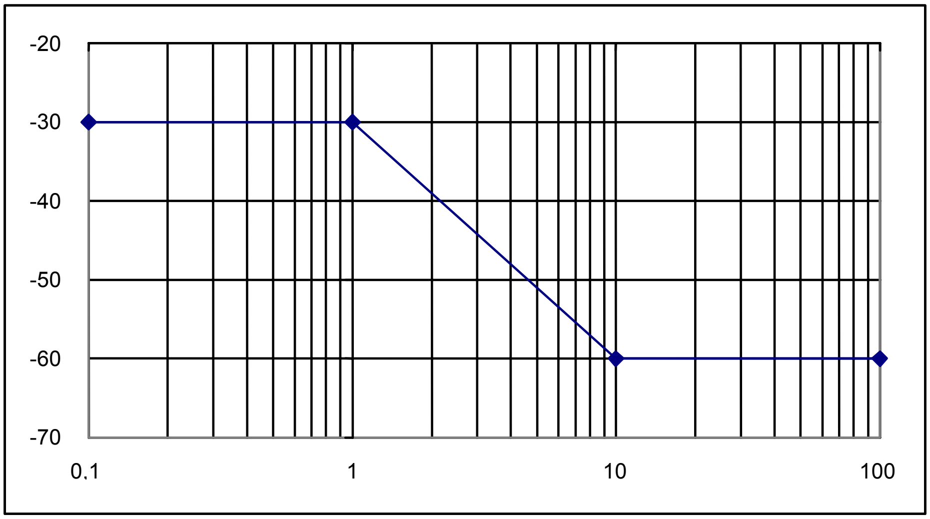


Figure F-2: Discrete Lines Template for the Transmitter (Normalized Power in dBc vs. Normalized Frequency: f/A)

F5.6 DOPPLER TRACKING AND ACQUISITION REQUIREMENTS

NOTE – The Doppler acquisition and tracking requirements imposed on any of the network elements are specified according to radio frequencies employed on the link. The requirement applies to the RF interface between all E1 and E2 elements. In the case of the coherent RF interface between E2c elements, there is an additional offset of Δf caused by the turnaround ratio of the responding element that must be tracked.

F5.6.1 UHF Frequencies

a) Doppler frequency range: ±10 kHz;

b) Doppler frequency rate:

   1) 100 Hz/s (non-coherent mode),

   2) 200 Hz/s (coherent mode).

NOTE – The Doppler frequency rate does not include the Doppler rate required for tracking canister or worst-case spacecraft-to-spacecraft cases.

F5.6.2 S-Band Frequencies

These requirements are intentionally left unspecified until a user need for them is identified.

NOTE – Users are requested to contact the CCSDS Secretariat, http://www.ccsds.org/secretariat.html, if such a need arises.

F5.6.3 X-Band Frequencies

These requirements are intentionally left unspecified until a user need for them is identified.

NOTE – Users are requested to contact the CCSDS Secretariat, http://www.ccsds.org/secretariat.html, if such a need arises.

F5.6.4 Ka-Band Frequencies

These requirements are intentionally left unspecified until a user need for them is identified.

NOTE – Users are requested to contact the CCSDS Secretariat, http://www.ccsds.org/secretariat.html, if such a need arises.

ANNEX G
PHYSICAL LAYER STATE TABLE

(This annex **is** part of the Recommendation.)

G1 PHYSICAL LAYER STATE TABLE

Table G-1 shows driven states (in gray) for the transmitter and receiver based on MAC state parameters.

Table G-1: Physical Layer State Table

State	Receiver State	Transmitter State	MODE	TRANSMIT	DUPLEX
P-1	*off*	*off*	*inactive*	N/A	N/A
P-2	*on*	*standby*	*connecting-L*	N/A	N/A
P-3	*on*	*asynchronous*	*connecting-T*	*on*	N/A
P-4	*on*	*synchronous*	*active*	*on*	*full*
P-5	*standby*	*synchronous*	*active*	*on*	*half*
P-6	*on*	*standby*	*active*	*off*	*half*
P-7	*on*	*off*	*active*	*off*	*simplex*
P-8	*off*	*synchronous*	*active*	*on*	*simplex*

NOTE – See the Proximity Layered Model (figure 2-1) for an overview of all interlayer parameters discussed below.

G2 PHYSICAL LAYER DEFINITIONS

G2.1 CONNECTION VARIABLE VALUES

a) *open* - proximity entities are not connected at the Physical layer; i.e., neither carrier nor bit lock has been achieved.

b) *closed* - a connection between Proximity entities at the Physical layer exists; i.e., carrier and bit lock have been achieved and are maintained.

c) *acquire_carrier* - a carrier-only signal is being transmitted for the purpose of acquisition.

d) *acquire_idle* - the idle sequence is modulated onto the carrier before the hail frame.

e) *tail_idle* - consists of the idle sequence modulated onto the carrier after the hail frame (to ensure processing of the hail frame through the convolutional decoder, if convolutional code applied).

G2.2 RECEIVER/TRANSMITTER STATES

a) *on* - Transmitter or Receiver is powered.

b) *standby* – Applies to half duplex operations for the receiver/transmitter or when MODE equals the *connecting-L* state for the transmitter. For half duplex operations, Receiver or Transmitter is placed into *standby* until either end of data is received or transmit or receive timers expire.

c) *off* - Transmitter or Receiver is depowered.

G3 CONTROL VARIABLE OPERATIONS

G3.1 CONNECTION state is as follows:

a) *open* whenever Transmitter State is either *off* or *standby*;

b) transitions from *open* to *acquire_carrier* to *acquire_idle* to *closed* when TRANSMIT transitions from *off* to *on*;

c) transitions from *closed* to *tail_idle* to *open* when TRANSMIT transitions from *on* to *off*.

G3.2 OUTPUT_BIT_CLOCK is provided to the Data Link layer only when CONNECTION is *closed* and PLTU_READY signal is *true*.

G3.3 RF_OUT contains:

a) *carrier_only* when CONNECTION state is *acquire_carrier*;

b) *idle_data* when CONNECTION state is:

   1) *acquire_idle, or*

   2) *tail_idle, or*

   3) *closed* and PLTU_READY is *false* and transmitter state is *synchronous.*

c) *pltu_data* (from C&S sublayer) when CONNECTION state is *closed* and PLTU_READY is *true*;

d) *idle_data* or *pltu_data* when CONNECTION state is not *open* and Transmit_Channel_Coding is *none*;

e) convolutionally coded *idle_data* or *pltu_data* when CONNECTION state is not *open* and Transmit_Channel_Coding is *convolutional*.

NOTE – *acquire_carrier*, *acquire_idle* and *tail_idle* are transient states that exist only for the time period dictated by the values in the respective MIB Parameters. These time periods are implementation specific based upon transceiver and the physical link characteristics.

ANNEX H

ABBREVIATIONS AND ACRONYMS

ARQ	Automatic Repeat Queuing
ASM	Attached Synchronization Marker
BER	Bit Error Rate
CCSDS	Consultative Committee for Space Data Systems
COP-P	Command Operations Procedure Proximity
CRC	Cyclic Redundancy Check
CW	Continuous Wave
DFC ID	Data Field Construction Identifier
FARM-P	Frame Acceptance and Rejection Mechanism Proximity
FDU	Frame Data Unit
FIFO	First In First Out
FOP-P	Frame Operations Procedure – Proximity
IPV4	Internet Protocol Version 4
ITU	International Telecommunications Union
MAC	Medium Access Control
MIB	Management Information Base
MSB	Most Significant Bit
N(R)	Last acknowledged frame sequence number +1
OSI	Open Systems Interconnection
PC	Physical Channel
PCID	Physical Channel ID
PCM	Pulse Code Modulation

PDU	Protocol Data Unit
P-Frame	Supervisory/Protocol Frame
PLCW	Proximity Link Control Word
PLTU	Proximity Link Transmission Unit
PSK	Phase Shift Keyed
QOS	Quality of Service
RF	Radio Frequency
RHCP	Right Hand Circular Polarized
R-S	Reed-Solomon
Rx	Receive
SAP	Service Access Point
SC	Spacecraft
SCID	Spacecraft Identifier
SCPS-NP	Space Communications Protocol Standards-Network Protocol
SDU	Service Data Unit
SPDU	Supervisory Protocol Data Unit
TX	Transmit
U-frame	User Data Frame
UHF	Ultra High Frequency
VE(S)	Value of the Expedited Frame Sequence Number
V(S)	Value of SEQ_CTRL Frame Sequence Number